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IN THE UNITED STATES PATENT & TRADEMARK OFFICE

APPLICANT: MICHAEL E. TOMPKINS ET AL §
§ GROUP ART UNIT: 2314
SERIAL NO.: 08/162420 §
FILING DATE: DECEMBER 3, 1993 §
§ EXAMINER: E. RAMERIZ
FOR: SPA CONTROL SYSTEM §

DECLARATION OF EDWIN T. LOVE
UNDER 37 C.F.R. 1.132

Commissioner of Patents & Trademarks
Washington, D.C. 20231

Date: May 10, 1994
Docket No.: 86-1198-00

Sir:

The undersigned, Edwin T. Love, states as follows:

1. My name is Edwin T. Love, I am over the age of twenty-one, have never been convicted of a felony, and am competent to give this Declaration. The following statements are of my own personal knowledge.

2. I have been employed in the industrial control field since 1976, and I have been integrating Programmable Logic Control (PLC) systems into process control applications since 1979. My specific education in this field has consisted of many training courses provided be Texas Instruments, Inc., where I have been certified as an Application Engineer for their PLCs, Control Vision Units, and Video Programming Units. During the period of 1981 to 1990 I worked as a PLC programmer for a distributor of Texas Instruments, Inc. PLC products. Since 1990 I have been gainfully employed as a contract PLC programmer working for various industrial automation companies. Some of the process control applications that I have designed and/or programmed PLCs for include; plating operations, batch pasteurization, and water treatment facilities. My experience with Input/Output (I/O) devices includes; operator interface units, transmitters (flow, temperature, pressure and pH), control valves, variable frequency drives, and motor control devices.

3. I have programmed and designed process control systems with the specific products referenced in this Declaration before May 27, 1987.

4. I have read the patent application number 054581 stamped May 27, 1987. Other than the typographical errors, the application is clear and exact to enable me to construct a working model with an off-the shelf PLC system, such as that manufactured by Texas Instruments Inc. prior to May 27, 1987 and would have enabled me to make and use the invention using this type of PLC system on May 27, 1987 without excessive training, research or analysis.

5. Exhibit A contains a diagram of a spa control system utilizing the Texas Instruments, Inc. Model 520C PLC and other external components that could have been purchased and used before May 27, 1987 to provide all the hardware and I/O functions listed in the above-referenced application, and could be programmed to provide the control system described in such application.

6. This section contains a brief description of the system shown in Exhibit A. The system contains an Operator Interface panel (1) which can be configured to perform as the Spa Control Panel as described in the above referenced application. The Operator Interface is a programmable device that contains its own electronics and can directly communicate with the PLC to allow the user to monitor and change the various system parameters. The Operator Interface has a two line by 20 character vacuum-fluorescent display and a membrane keypad and is connected to the PLC via a Communications Cable (2). Both the Operator Interface and the PLC system are powered by a 24 Volt DC power supply (3). The PLC system consists of an I/O Base (4), Base Power Supply (5), Central Processing Unit (CPU) (6), Digital Input Module (7), Digital (relay) Output Module (8), and an Analog Input Module (9). The I/O Base (4) holds all the modules which make-up the PLC system. The I/O Base has 1 slot for the Base Power Supply, 1 slot for the CPU and 6 slots available for the I/O modules. The Base Power Supply provides power to the other modules via a bus on the I/O backplane. Similarly, the CPU communicates with the I/O modules via a bus on the I/O backplane. The CPU has 4096 words of Random Access Memory (RAM). The PLC configuration program is stored in the RAM which is backed-up by a lithium battery to preserve its

contents during a main power failure. An Electrically Erasable Programmable Read Only Memory (EEPROM) can be added, if required, to preserve the program indefinitely. The CPU contains its own microprocessor and is programmed internally by the manufacturer to execute the external instructions of a control system programmer. These instructions are formulated in a language called Relay Ladder Logic (RLL). The CPU can be programmed as required for the spa control application, including an algorithm for Proportional, Integral and Derivative (PID) control. Once the control program is configured in RLL, it is loaded into the PLC using an IBM or compatible personal computer via a communications cable, as described in the PLC users manual attached in Exhibit D. The CPU will receive operating setpoints from the user via the Operator Interface. The CPU will receive field conditions via the Digital Input Module (e.g. flow switch), and Analog Input Modules (e.g. Temperatures and pH). The CPU will send operational information to the Operator Interface and send commands to the field devices (e.g. Jets pump, Heater, Blower) via the Digital Output Module. The Digital Input Module (7) receives digital statuses from the field devices and passes that information to the CPU. The Digital Input Module uses opto-isolators to electrically shield the PLC system from the field devices. The Digital Output Module (8) receives digital statuses from the CPU which it passes on to the field devices which are connected to it. The Digital Output Module has eight relays which are individually energized as requested by the CPU. When a relay is energized it closes a set of contacts which pass the field supplied voltage to the field device. The Analog Input Module (9) receives analog signals from the field devices and passes that information on to the CPU. Typically, the analog inputs from the temperature or pH sensors are in the range of 4-20 ma or 1 to 5 Volts DC. If the input is 4-20 ma it is converted to 1-5 Volt DC by an internal resistor in the module. The Analog Input Module will convert the voltage to a digital value (A-D conversion) which can be interpreted by the CPU. The Operator Interface contains a real-time clock, whose information can be downloaded to

the PLC for controlling the scheduled events of the spa control program.

7. The hardware description in the previous section is very similar to the description, and provides the same functions, of the hardware components in the above-referenced application.

8. I could, from the above-referenced application, interpret and transform the verbal descriptions of the control system operation into flowcharts that would subsequently be used to write the actual configuration program for the PLC. Examples of flowcharts for the Blower logic, the Set Temperature logic, and the No Water Flow logic alarm, are shown in Exhibit B attached to this Declaration.

9. Exhibit C contains actual relay ladder logic programs to perform the operations of the flowcharts in Exhibit B as described in the above-referenced application. The remaining portions of the program could be programmed, just as easily as these were, by the same sequence of converting the verbal descriptions of the control functions into flow charts and then into the actual RLL program.

10. After preparing the items for Exhibits A, B and C, I read the Second Declaration of Michael E. Tompkins, dated May 9, 1994, and I agree that the entire control system could have been created with the devices described in the Declaration, or those from many other manufacturers, by someone skilled in the art of control system design, without excessive training, research or analysis before May 27, 1987.

11. I have read a copy of the Examiners Answer dated July 12, 1993 and the Office Action of March 10, 1994. I disagree with the Examiners conclusion that detailed descriptions of the internal operations of the control system, or the components that implement specific control functions, are required to produce the invention of the above-referenced application. Descriptions of these functions and components were available to the field to persons using electro-mechanical devices, before May 27, 1987, and would have enabled such persons to configure control systems using such devices. The descriptions of the functions such as I/O scanning,

analog multiplexing and similar functions, and the integration of such functions in one device, are available from many sources, including the users manuals of PLCs. Someone skilled in the art of integrating PLC control systems into process control applications is not concerned with the specific operations of the internal hardware components performing the functions of the control system.

12. For example, the pH and A-D algorithms needs no further discussion because it is understood, by someone skilled in the art, that a pH probe would present a varying analog signal, representing a pH value, to the PLC, and this signal would be converted into a digital number by the A-D converter in the PLC. The action of the A-D conversion occurs without intervention by the programmer except to tell the PLC which analog input is attached to the pH probe. If a special algorithm where needed to convert this digital number to an actual pH value in engineering units, one of ordinary skill for implementing controls, would only need to consult the literature of the pH probe manufacturer to acquire an equation for that particular probe. This simple equation would then be included as part of the PLC's ladder logic program as shown in various examples in the users manual attached in Exhibit D.

13. I hereby declare that all statements made herein of my own knowledge are true and that all statements on information and belief are believed to be true; and further that these statements were made with the knowledge that willful, false statements and the like so-made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful, false statements may jeopardize the validity of the above-referenced application or any patent issued thereon.

Edwin T. Love

EDWIN T. LOVE

5-18-94

DATE

FIG. 1

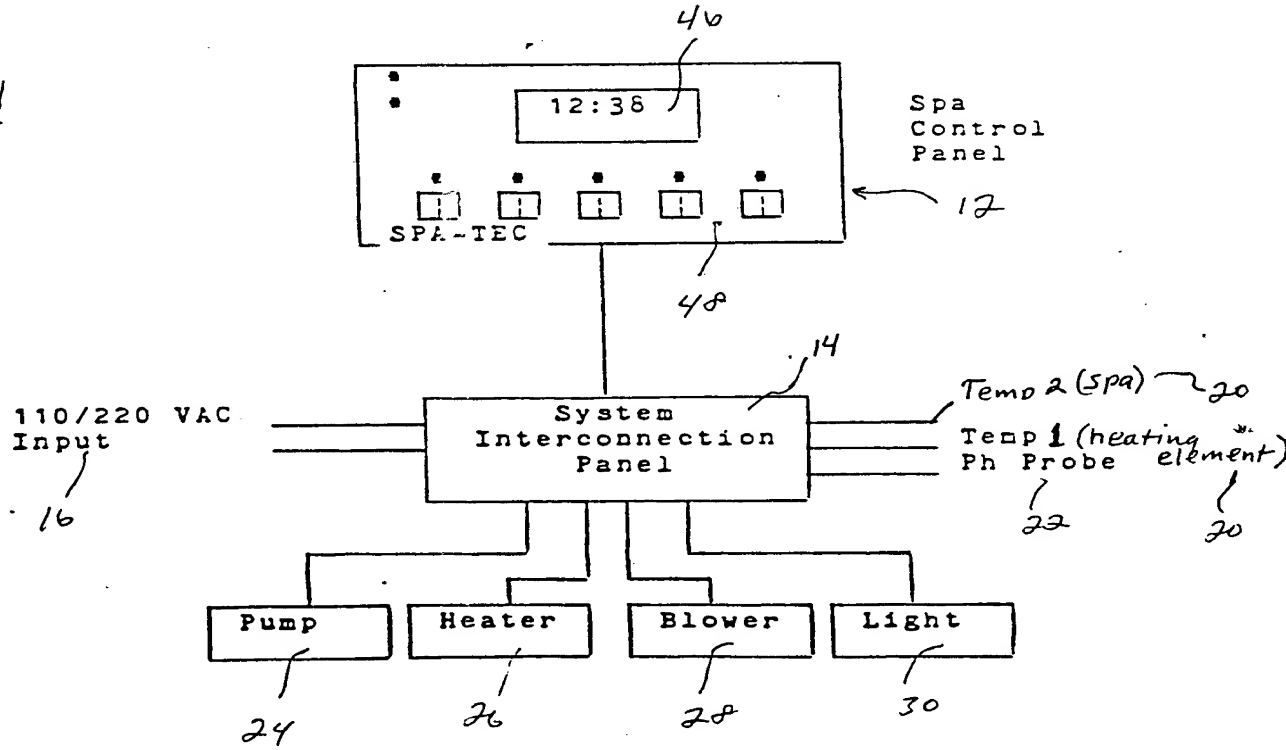
40
12:38
Spa
Control
Panel
12
SPA-TEC
48
14
System
Interconnection
Panel
110/220 VAC
Input
16
Temp 2 (Spa)
20
Temp 1 (heating element)
Ph Probe
22
20
Pump
Heater
Blower
Light
24
26
28
30

EXHIBIT A

5/23/94

Delete chlorine

Make Display 7 Segment VS Alphanum

Delete Second Aux Circuit

~~AQUATROL~~

Description and Theory of Operation

1. General Description

Aquatrol is an intelligent microcomputer controlled device used for the control and monitoring of spas. The Aquatrol is designed with current technology solid state electronic components, eliminating the problems associated with older mechanical timer and relay control systems. All electronic control means high reliability and low maintenance. Figure 1-1 shows a block diagram of the Aquatrol system and its interface to the spa components.

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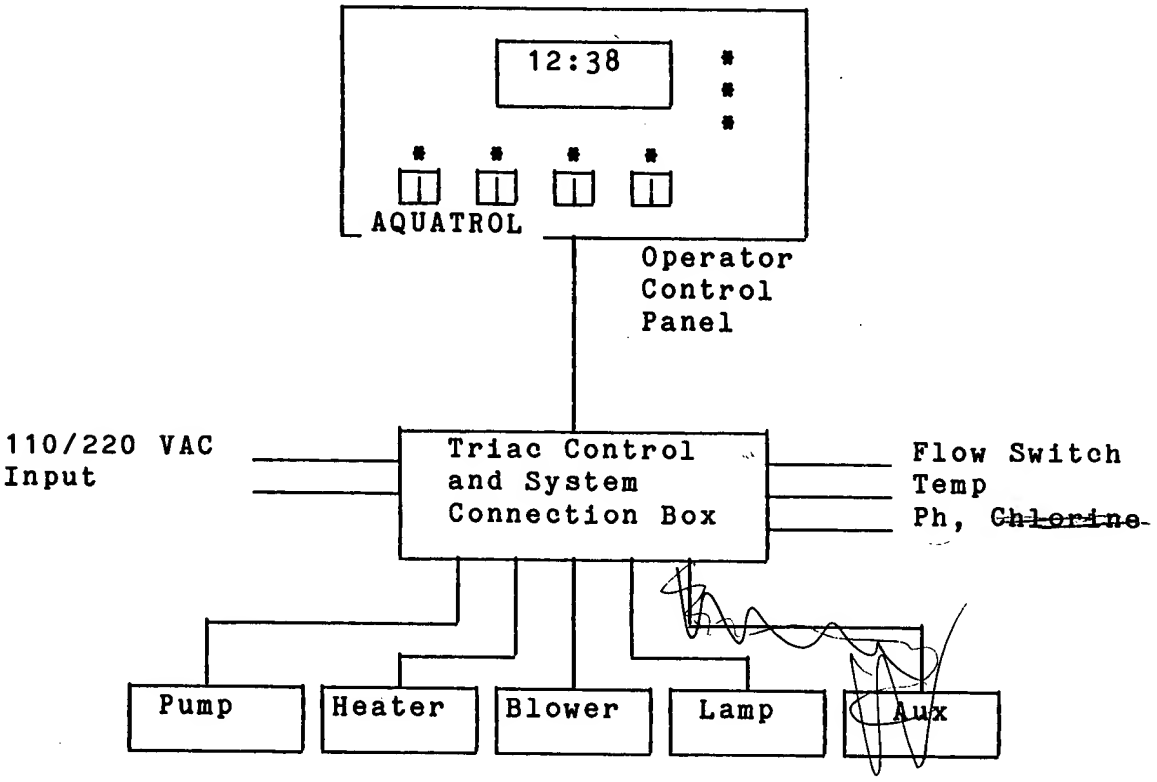


Figure 1-1
Aquatrol System Diagram

The unique design allows the Operator Control Panel to be located spaside thus eliminating the need to exit the spa just to change the temperature or to turn lights on and off in the spa or gazebo.

The high speed microcomputer and associated monitoring circuitry allow easy setting of the water temperature and precise regulation.

All user interface to the Aquatrol is made simple and easy through "user-friendly" programming and single button commands. Time and spa temperature are constantly displayed on the Operator Control Panel. The system allows you to set certain times of the day for the spa to circulate. You can even preset the time and date for the spa to heat so it will be ready when you are.

The system has the capability to display error messages or give you instructions on where a possible problem may be. Messages such as "Heater not functioning" or "Flow switch open" are just a couple of examples.

Aquatrol allows you to throw away those messy pool test kits with its optional Ph and Chlorine monitoring devices. Lamps on the Operator Control panel even alert you when the levels deviate to unacceptable points.

Aquatrol is modular in design making servicing simple and easy if it is ever required. The computer even has diagnostics to monitor itself and give the results to a service technician.

2. Hardware Description

Since the Aquatrol will be subjected to various environmental conditions the electronics was designed to handle temperature extremes of -40 to +85 Degrees C (-40 to +185 Degrees F). The technology used in this design is Complementary Metal Oxide Semiconductors (CMOS) which is low in power consumption and high in reliability. The design is based around readily available components which are second sourced by several manufacturers which will ensure a long product life.

Figure 2-1 shows the block diagram of the Aquatrol microcomputer and its associated components. Each of the blocks will be described in detail in the following sections.

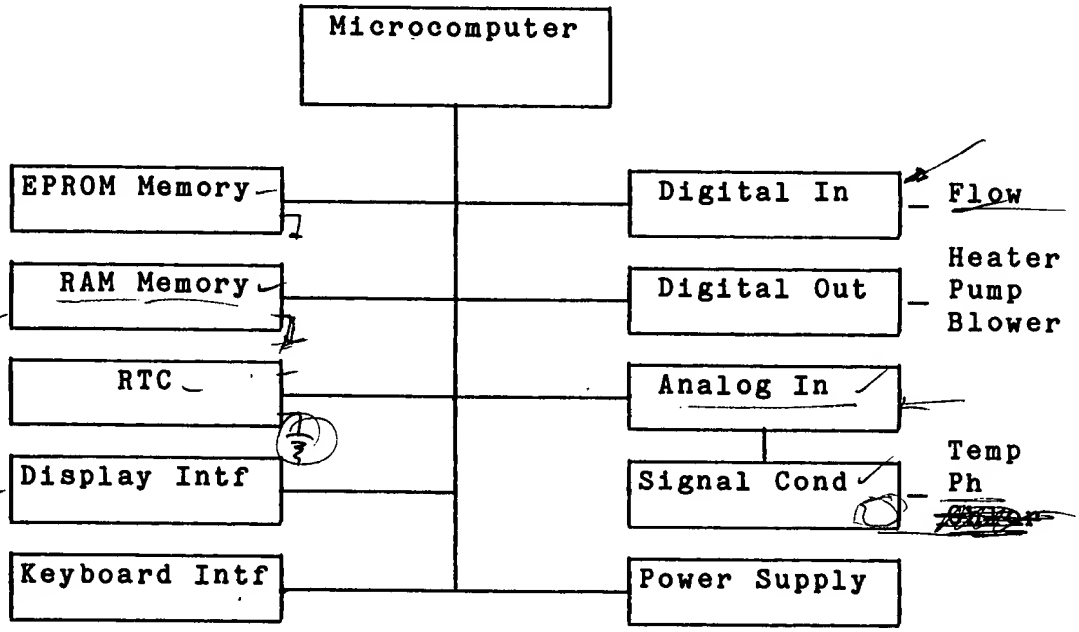


Figure 2-1
Microcomputer Block Diagram

2.1 Microcomputer

The microcomputer is a 16-bit control device with an 8-bit data bus. Its purpose is to execute instructions, control processes, make logical decisions and compute values. It operates at a clock speed of 5 megahertz and can make thousands of decisions and calculations per second.

2.2 EPROM

The Electrically Programmable Read Only Memory (EPROM) is the device which stores the instructions for the microcomputer to execute. Once a program is created on the development system the final software is loaded into the EPROM device.

The EPROM is a read only device meaning that the microcomputer cannot write data to its memory.

EPROMS can be changed in the future to add new features, or the same hardware can support several different products just by supplying different EPROMs for different applications.

2.3 RAM

The Random Access Memory (RAM) is a memory device which the microcomputer uses to store temporary information while it is processing. Reading and writing data is possible with this device. Since the RAM is battery backed, it can hold data for future reference even when the main AC power is off. Examples of data that might be stored are the number of hours on the heater, the number of times the spa has been over temperature, etc.

2.4 RTC

This is the Real Time Clock/Calendar (RTC). Its purpose is to keep the accurate time and date. The microcomputer can use this information to schedule events such as when to turn the spa on, when to circulate the water, etc. The RTC is also battery backed so that accurate time will be kept even when main power is off.

2.5 Display Interface

This circuitry is responsible for driving and updating the display device. When the microcomputer sends information to this block it is decoded and displayed on the screen. The data will remain on the screen until the microcomputer sends a new message or the system is powered off or reset.

2.6 Keyboard Interface

This circuitry allows the microcomputer to listen to the keyboard. It conditions the signals and allows only one key at a time to be active. The microcomputer is signaled whenever a key is pressed and then reads the key data and acts upon it if necessary.

2.7 Digital Inputs

This section monitors digital inputs from external devices such as the flow switch or other push-buttons. All field digital inputs are optically isolated from the microcomputer to prevent static and surges from entering the system. The inputs have transient and surge protection devices installed on each line.

2.8 Digital Outputs

This section drives the external output devices such as the blower, heater, pump and auxiliary devices. The low voltage signals are optically isolated and then drive a TRIAC device which provides the high voltage and high current required by the external devices.

2.9 Analog Inputs

The analog input section converts information from various sensors into digital information so the microcomputer can read these inputs. The converter translates the analog information into digital by a process known as dual slope integration which allows fast and accurate conversions. The accuracy of the A-D is 8 bits or a resolution of 1 out of 256.

2.10 Signal Conditioning

This section receives the small signals from external probes and amplifies it to a level where the A-D converter can make an accurate conversion. This section also provides transient and surge protection to eliminate problems with static and noise.

2.11 Power Supply

The power supply converts the 110 or 220 Volt AC incoming power to the spa into the low voltage and low power required by the controller. This section also contains the battery used to provide power to the RTC and RAM when main power is off.

3. Software

Software is the set of instructions which tell the microcomputer what to do and how to do it. The software is created on another computer or development system then the final software code is transferred to the EPROM device on the Aquatrol for operation.

The software is written on the development system in a language called "C". This is a well documented, efficient and easy to learn structured programming language.

Figure 3-1 contains the basic block diagram for the functional pieces of the Aquatrol software. These functions will be explained in detail in the following sections.

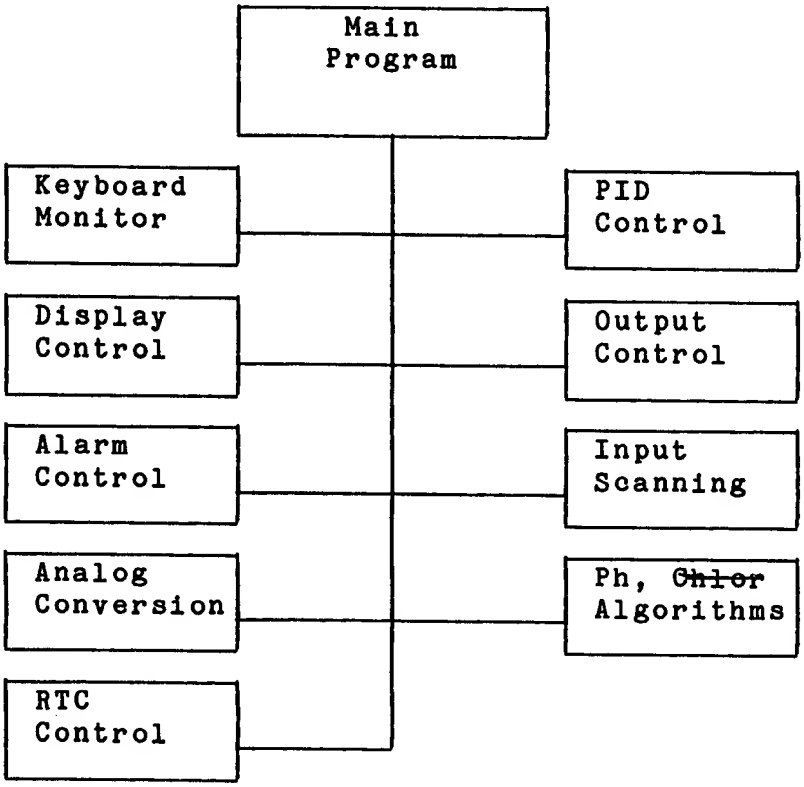


Figure 3-1
Software Functional Block Diagram

3.1 Main Program

The main program is responsible for the scheduling of tasks of other programs and the general housekeeping chores of the processor such as memory management, timer control, interrupt handling, task scheduling, etc.

3.2 Keyboard Monitor

This program scans the keyboard looking for a key to be pressed. When this occurs the key will be decoded and the main program will then cause the series of events associated with that key to occur. If more than one key is associated with a command the program will wait for the next entries before any action is taken. This program will ignore multiple key depressions and erroneous entries.

3.3 Display Control

The Display Control program converts data from the memory to readable messages to send to the display. It also handles the necessary timing and control signals to make the display perform in an efficient and proper manner.

3.4 Alarm Control

This program monitors the conditions that could occur to allow the system to operate incorrectly or to malfunction. Examples of this are not letting the heater operate if the flow switch is not active, or not letting the heater operate if the flow switch is active when the pump is not on indicating a clogged or broken flow switch. This program will also monitor the Ph and chlorine levels and compare them to preset high and low values. Messages will be sent from here to the display controller to alert the user of a problem.

3.5 Analog Conversion

The Analog Conversion program manipulates the A-D converter circuitry to convert the sensor input signals to digital information. This program also converts the digital information to engineering units for purposes of comparison and displaying.

3.6 RTC Control

This program controls all interaction with the Real Time Clock/Calendar. It is responsible for writing new data to its internal registers, as well as loading data for events which are scheduled in the future.

3.7 PID Control

PID stands for Proportional, Integral and Derivative. This is the program which performs the closed loop control on the heating element. It will monitor the temperature of the water and determine if the heater should come on. If so it will issue a command to activate the heater then monitor the temperature to determine when to turn it off. This program is more than just a On-Off controller however. It monitors the rate of decrease and the rate of increase of the water temperature so as not to allow it to undershoot or overshoot. Typical accuracies of +/- 1 Degree Farenheit are possible with this type of control and the proper system heating elements.

3.8 Output Control

The Output Control program issues commands to the output components to turn on the TRIACs for control of the pump, heater, blower, lights, etc.

3.9 Input Scanning

Input scanning monitors devices such as push buttons and switches. The flow switch would be monitored by this program as well as any other shutdown or feedback signals.

3.10 Ph, Chlorine Algorithms

This program converts the raw digital data from the A-D converter to absolute real values. The algorithms consist of scaling, offsetting, multiplying by temperature factors, etc.

4. Packaging

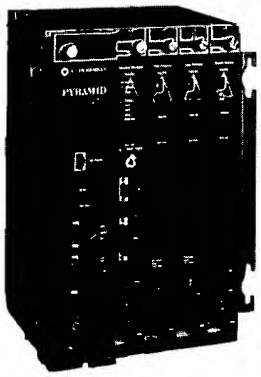
The packaging of the Aquatrol system would consist of two major pieces, the Operator Control Panel and the TRIAC and connection box. The OCP will be an ABS plastic weather tight enclosure approximately 6" W x 5" H x 3" D. A Stainless steel or plastic support pole could be used to mount the OCP to the side of the woodwork around the spa. A swivel mount would be preferred. The interface cable between the two units could be hidden and protected inside this mounting assembly.

The second box will be approximately 9" W x 9" H x 4" D. This will allow plenty of room for interface connections and the TRIAC mounting plate.

E X H I B I T B

PLC-5/250 Programmable Controller Processors

(Cat. Nos. 5250-LP1, -LP2, -LP3, -LP4)



The PLC-5/250 processor is the largest member of the PLC-5 family of programmable controllers. As a member of the Allen-Bradley Pyramid Integrator, system, this advanced processor is ideal for large integrated control and information-processing applications.

The PLC-5/250 processor is modular. You can have a maximum of four logic-processor modules for maximum memory and program processing power. You can have a maximum of four remote scanner modules for maximum I/O precessing power.

The PLC-5/250 processor supports a superset of 1785 PLC-5 instructions, including complex math, data-manipulation, and smart-directed sequencer (SDS) instructions for diagnostics and state control.

UP to four PLC-5/250 logic-processor modules can be mounted in a single chassis organized to either:

- Run a single program where a complex task requires, fast, parallel processing to optimize performance
- Run individual programs while communicating with each other for close-coupled multi-process coordination

Each PLC-5/250 processor can support:

- A main application program while performing up to 64 background tasks for non-time-critical functions
- Four hard-wired processor input interrupts to activate subroutines based on user determined process events
- Eight programmable timed interrupts

The PLC-5/250 controller can be enhanced with the addition of other modules including:

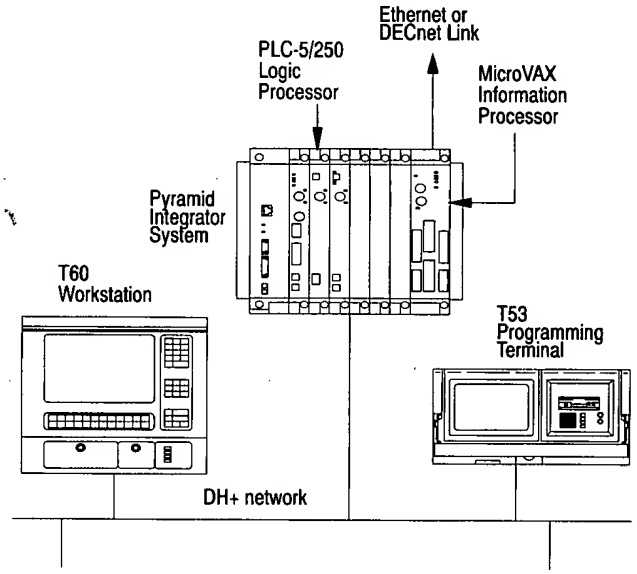
- Multiple PLC-5/250 Logic Processors
- CVIM™ Module, CVIM2, color CVIM
- MicroVAX Information Processor Module
- Data Highway/Data Highway Plus Communication Interface Modules
- Multiple I/O scanners
- OSI (MAP/MMS) communications
- Ethernet Interface

Specifications

I/O capacity (any mix)	4096
Maximum number of I/O racks [1]	32 (remote)
Compatible types of 1771 I/O modules	• intelligent and discrete • block-transfer and single-transfer • up to 16 analog I/O per module • up to 32 digital I/O per module
Memory capacity (in 16-bit words)	• Each RM: 128K or 384K • Each LP: 256K, 512K, 1M, or 2M • Each RS: 8K
Memory type	Battery-backed RAM
Program scan time	• 0.5ms/Kwords minimum • 2ms/Kwords typical
I/O scan time/rack (in a single chassis)	• 9ms @ 57.6k bit/s • 5ms @ 115.2k bit/s • 3ms @ 230k bit/s
Number Selected Timed Interrupts	8 per logic-processor module
Number Independent Background Programs	4 per logic-processor module

[1] I/O rack — an I/O addressing unit that can contain a maximum of 128 I/O with unique addressing of I/O modules or 256 I/O with duplicate addressing of I/O modules.

Typical Configuration



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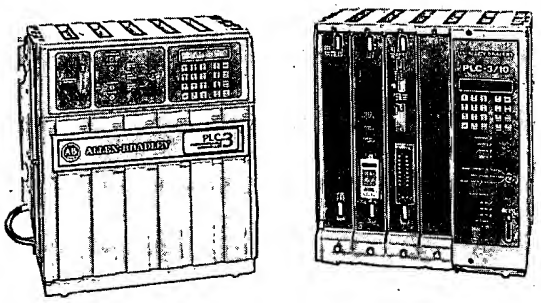
PLC-3 Family Programmable Controller Processors

(Cat. Nos. 1775-L3, -LP)



PLC-3 family of controllers have modular processors that allow configuration flexibility and expandability:

- The PLC-3 processor is designed for large-scale applications and can be expanded to 1.92M words of user memory (3.84M words with 256K-word memory module)
- The PLC-3/10 processor is designed for mid-sized applications and comes with pre-configured system components

Features

- Selectable communication rates
- Multiple contexts for storing more than one program in memory
- Programmable fault response for reacting to a fault before the system goes down
- Timed-interrupt routine for examining specific information at specific time intervals
- Selectable I/O scan priority by repeating I/O chassis in I/O scanning sequence
- Local data-access panel for troubleshooting, configuration, data-table manipulation, and processor status information
- Built-in Data Highway Plus channel on 1775-SS/SRS Scanner Module to link processors together without additional modules
- Hot backup to avoid costly downtime by switching over to a backup processor should the primary processor fail
- Alternate GA-BASIC language through the 1775-GA module

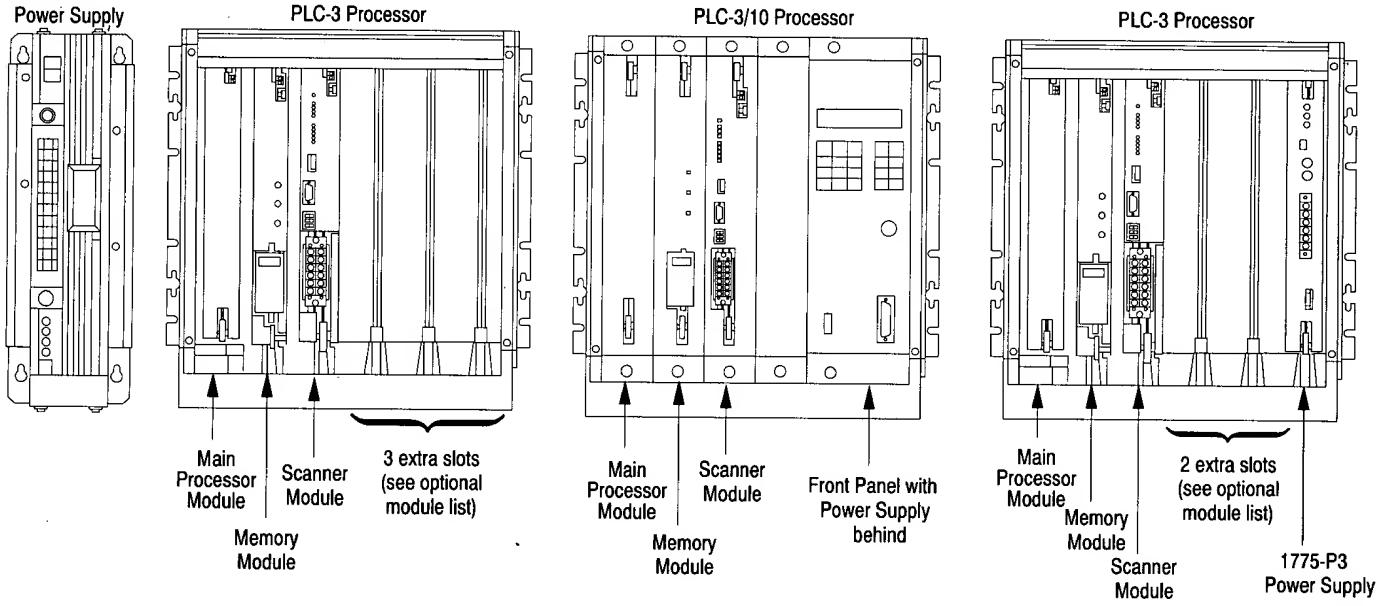
Specifications

PLC-3/10 I/O capacity	• 2048 (any mix) • 2048 in and 2048 out (with complementary I/O module placement)	
PLC-3 I/O capacity	• 4096 (any mix) • 4096 in and 4096 out (with complementary I/O module placement)	
Maximum number of I/O chassis	• PLC-3 = 256 • PLC-3/10 = 128	
Compatible types of 1771 I/O Modules	• intelligent and discrete • block-transfer and single-transfer • up to 16 analog I/O per module • up to 32 digital I/O per module	
Maximum memory capacity	• PLC-3 = 1.92M words (3.84M words with 256K memory module): • PLC-3/10 = 128K words	
Over 70 programmable instructions	control tasks such as : • timing • counting • data transfer and comparisons • file movement • diagnostics • floating-point math • logic conditions	
Memory type	Error Detecting and Correcting (EDC) CMOS RAM	
Program scan	• 1.0ms/K (min) • 2.5ms/K (typical)	
I/O scan/rack	in a single chassis with	
	4 I/O channels active	1 I/O channel active
	• 8ms @ 57.6k bit/s • 6.5ms @ 115.2k bit/s • 6ms @ 230k bit/s	• 7ms @ 57.6k bit/s • 4.5ms @ 115.2k bit/s • 3ms @ 230k bit/s
Dimensions (W x H x D)	483 x 508 x 368 mm (19 x 20 x 14.5 in)	
Input power requirements	• PLC-3 with1775-P1 = 120/220V ac, 600VA • PLC-3/10 with 1775-P3 = 115/230V ac, 370VA	

PLC-3 Family Programmable Controller Processors

(Cat. Nos. 1775-L3, LP)

Typical Configurations



Required Components

Component Type	PLC-3 System Component Cat. No.	PLC-3/10 Pre-configured System (1775-LP) Component Cat. No.
Processor chassis	1775-A1, -A2	1775-A3
Power supply	1775-P3, 1775-P1	1775-P3
Industrial terminal	1770-T4, 1784-T50, 6160-T53	1770-T4, 1784-T50, 6160-T53
Main Processor module	1775-L3	1775-L4
I/O Scanner	1775-S4A, -S4B, -S5	1775-SR5, -SR
Memory Module	1775-ME4 (16K) 1775-ME8 (32K) 1775-MEA (64K) 1775-MED (128K) 1775-MEF (256K)	1775-MS4 (16K) 1775-MS8 (32K) 1775-MSA (64K) 1775-MSD (128K)

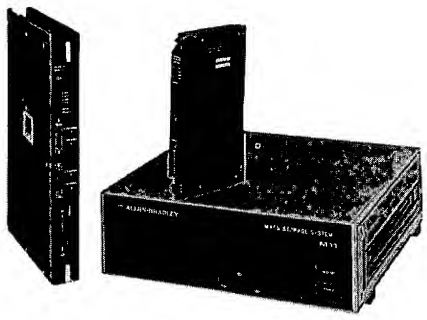
[1] Although required, the programming terminal and memory are not included with the PLC-3/10 pre-configured system.

Optional Modules

Module	Cat. No.	Function
Memory	see above	Additional memory for a PLC-3 system only
I/O scanner	1775-S4A (PLC-3); 1775-SR (PLC-3/10)	Additional scanning functions
I/O scanner-communication adapter	1775-S5 (PLC-3); 1775-SR5 (PLC-3/10)	Additional I/O scanning, interface to Data Highway or Data Highway Plus links
Expansion	1775-LX	To connect up to three expansion chassis to the main chassis (PLC-3 system only)
Memory communication	1775-MX	Memory communication between backup and primary processors configured for hot backup
I/O scanner-message handling	1775-S4B	I/O scanning and report generation (for a PLC-3 system only)
Peripheral communication	1775-GA	GA BASIC, RS-232-C device interface, and 1770-M11 mass storage interface
Communication adapter	1775-KA	Interface to Data Highway or modem link
Communication interface	1775-KP3, -KP3R	Interface to Data Highway II link
MAP interface	6633-P3	Interface to MAP link
IBM Memory Communication Module	1775-MZ	Interface to IBM AT computers or compatible

PLC-3 Family Peripheral Communication System

(Cat. Nos. 1775-GA, -RM, 1770-M10, -M11)



The peripheral communication system lets you obtain, organize, store, and retrieve information concerning production data and plant operation. It brings to the PLC-3 family many of the most frequently used personal-computer-like functions including bulk storage on hard disk, extensive report generation, LIST functions, search functions, and many others.

The PLC-3 Family Peripheral Communication System consists of these modules:

- 1775-GA Peripheral Communication Module — provides extensive communication features, including mass storage interface, data cartridge recorder (cat. no. 1770-SB) interface, GA BASIC programming, and ladder logic programming
- 1775-RM Peripheral Interface Adapter Module — enables communication to the peripheral communication module up to 10,000 cable feet away
- 1770-M11, 1770-M10 Mass Storage Systems — lets you create a library of programs, procedures, and/or files on micro-floppy or Winchester disk and can provide trending capability

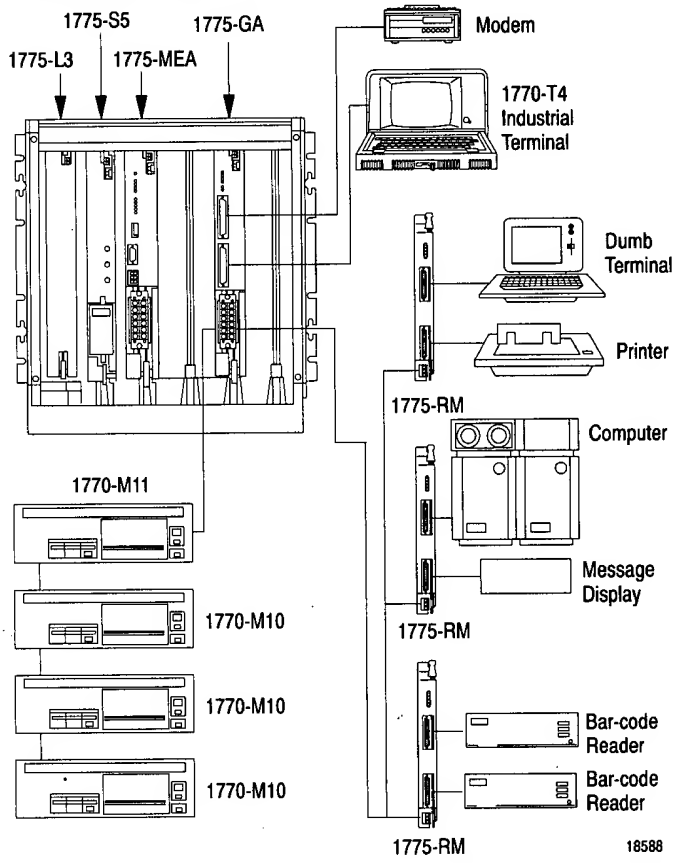
Features

- Multi-tasking and remote operation for greater efficiency
- GA BASIC programming language to perform functions such as data logging, sampling, trending, on-line editing, report generation, block-transfers, floating-point math, and trigonometric functions
- Micro-floppy and hard-disk storage for historical trending or data logging

Specifications

Peripheral Communication Module (1775-GA)	
Location	any slot in a PLC-3 or PLC-3/10 processor chassis
Channels	• 4 local RS-232-C • 2 remote
Channel cable length	• up to 50 ft per local channel • up to 10,000 cable ft per remote channel
Peripheral Interface Adapter Module (1775-RM)	
Location	any module slot in a 1771 I/O chassis
Channels	2-RS-232-C
Maximum cable length	at communication rate on remote link between 1775-GA and 1775-RM: • 10,000 cable ft @ 57.6 bit/s • 5,000 cable ft @ 115.2 -bit/s from 1775-RM to RS-232-C device • 50 cable ft
Modules per remote channel	16 max
Mass Storage Systems (1770-M10, -M11)	
Hard disk drive	storage: 22.25 Mbytes data transfer: 625 Kbytes/s
Micro-floppy disk	size: 3.5 inch, double sided disk storage: 655,360 bytes data transfer rate: 250K bits/s
Dimensions (DxWxH)	42.4 x 13.3 x 42.9 cm (16.7 x 5.3 x 16.9 in)
Channel usage	Uses one remote channel

Typical Configuration



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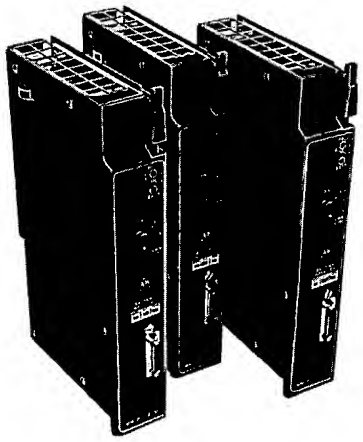
Mini-PLC-2/02, -2/16, -2/17 Programmable Controller Processors

(Cat. Nos. 1772-LZ, -LZP, -LX, -LXP, -LW, -LWP)



Mini-PLC-2/02,-2/16 and -2/17 processors are single-slot processors that mount in a 1771 1/0 chassis. With features like selectable timed interrupts, jumps and subroutines, file-to-file moves, expanded mathematical functions, and FIFO load and unload, you can handle complex processes that would normally require a much larger programmable controller.

Features

Mini-PLC-2/02 and -2/16

- Advanced math functions including up to 6-digit 4-function math operations, square root, binary/BCD conversion, Log_{10}, 10^x, sine, cosine

Mini-PLC-2/17

- Advanced math functions including up to 6-digit 4-function math operations,square root binary/BCD conversions, Log_{10}, 10^x, sine, cosine
- Advanced math functions including Y^x, e^x, Log_e, reciprocal, averaging, and standard deviation

Specifications

Processor Catalog Numbers	• Mini-PLC-2/02 (cat. no.1772-LZ,-LZP) • Mini-PLC-2/16 (cat. no.1772-LX, -LXP) • Mini-PLC-2/17 (cat. no.1772-LW, -LWP)
I/O Capacity (any mix)	512
Maximum number of I/O Racks	4
Compatible Types of 1771 I/O Modules	• intelligent and discrete • block-transfer and single-transfer • up to 16 analog I/O per module • up to 32 digital I/O per module
Memory Capacity	Mini-PLC-2/02: 2K words Mini-PLX-2/16: 4K words Mini-PLC-2/17: 7.75K words
Memory Types	• battery-backed RAM • EEPROM program backup option using 1772-MJ module
Program Scan (minimum)	7.5 ms/K
I/O Scan (minimum)	1 ms
Location	leftmost slot of I/O chassis
Input Power Requirements for 1772-LZP	120/220 V ac, 100 VA
Output Current Supplied to Backplane by 1772-LZP, -LXP, -LWP	4A supplied
Backplane Current Required for 1772-LZ, -LX, -LW	1.25A load

[1] I/O rack — an I/O addressing unit that can contain a maximum of 128 I/O with unique addressing of I/O modules or 256 I/O with duplicate addressing of I/O modules.

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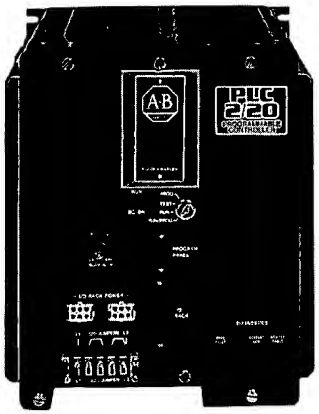
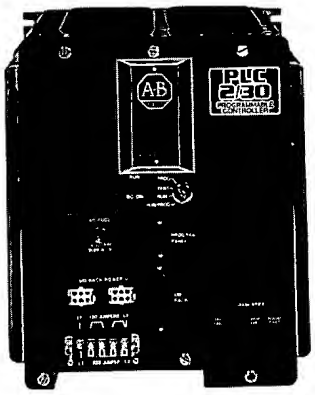
PLC-2/20 and PLC-2/30 Programmable Controller Processors

(Cat. Nos. 1772-LP2, -LP2D4, -LP3, -LP3D4)





The PLC-2/20 and PLC-2/30 processors feature rugged construction and proven reliability with a broad user base. With an installed base of over 30,000 units, both processors are virtually industry standards.

Each processor is capable of controlling up to 986 I/O in any mix. Each processor is capable of controlling local and remote I/O. Additionally, the PLC-2/30 processor has file-transfer instructions, bit- and word-shift registers, and sequencers.

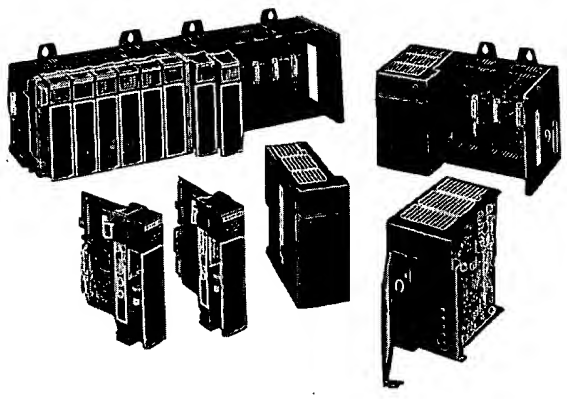
Features

- Addressing of both local and remote I/O chassis permits locating clusters of I/0 chassis near I/O sensors and loads
- Advanced instruction set for subroutine, block-transfer, file data transfer and sequencer programming (PLC-2/30 processor only)

Specifications

Processor Catalog Numbers	• PLC-2/20 = 1772-LP2, -LP2D4 • PLC-2/30 = 1772-LP3, -LP3D4
I/O Capacity	• 896 (any mix) • 1792 (complementary I/O)
Maximum Number of I/O Racks	up to 7 local or 14 remote
Compatible Types of 1771 I/O Modules	• intelligent and discrete • block-transfer and single-transfer • up to 16 analog I/O per module • up to 32 digital I/O per module
Memory Capacity (words)	• PLC-2/20 = 8K • PLC-2/30 = 16K
Memory Type	battery-backed RAM module: 1772-ME8 (8K words) 1772-ME16 (16K words)
Program Scan (minimum)	5 ms/K
I/O Scan (minimum)	• 0.5ms/AL • 7ms/AS
Dimensions (W x H x D)	12 x 13.5 x 8.9 inches (30.5 x 34.3 x 22.6 centimeters)
Input Power Requirements	24V dc, 120/220V ac, 75VA

[1] I/O rack — an I/O addressing unit that can contain a maximum of 128 I/O with unique addressing of I/O modules or 256 I/O with duplicate addressing of I/O modules.



The 1746 I/O platform provides more than 40 different modules to meet your application needs. It is available as both fixed and modular platforms to be compatible with any SLC 500 small programmable controller.

Fixed I/O is provided with a 2-slot expansion rack that expands the I/O capacity and functionality of an SLC 500 controller by providing up to 32 additional I/O. Its modular hardware design uses cost- and space-effective means to add I/O modules to your control system. As a family of I/O modules, 1746 I/O provides a platform from which the SLC 500 will continue to grow in the future.

The 1746 I/O platform currently offers one analog input module and two combination modules to provide a cost-effective solution for analog control. These modules offer a high level of resolution for accurate control in a broad range of analog applications.

Additionally, speciality I/O modules are available to enhance your control system. These modules include motion control and communication. They provide a unique, easy-to-use interface between the modules and the CPU.

Most SLC 500 devices are UL listed and CSA certified for Class 1, Division 2, Groups A, B, C, and D hazardous locations. See page 3-47.

Features

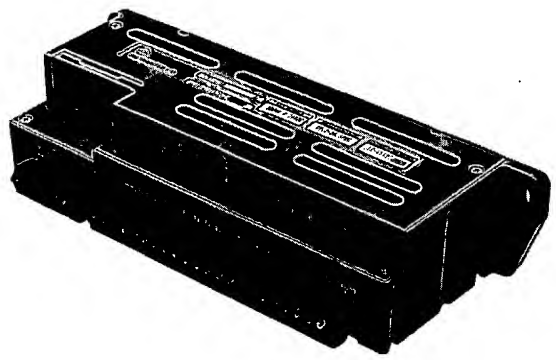
- Hardware-platform sharing makes spare-parts stocking convenient
- 4-, 8-, 16-, and 32-I/O modules create a variety of choices for cost-effective control solutions
- Combination modules provide expansion capabilities without sacrificing space or increasing cost
- Variety of voltages creates a precise power fit for your application

Specifications

For specifications and a listing of 1746 I/O modules, refer to the selection charts beginning on page 3-35.

For specifications and a listing of 1746 I/O chassis, see page 4-10.

995 over



An I/O block is a compact unit that contains not only I/O circuits, but also a built-in power supply and a built-in remote I/O adapter. An I/O block is compatible with a remote I/O scanner of a PLC or SLC programmable controller when connected on an Allen-Bradley universal remote I/O link. The I/O values are accessible from the PLC or SLC data table.

Typical Applications

Applications requiring I/O located close to sensors and actuators, or located in small enclosures.

Features

- Compact size of total package for I/O
- Low enclosure cost because of compact size
- Low wiring cost because I/O block can be located close to sensors and actuators
- Easy to replace without rewiring because of removable terminal strips
- Compatible with Allen-Bradley universal remote I/O link
- Blocks of 16 I/O can be mounted vertically or horizontally on a panel or DIN rail
- Loop power supplied for analog-input current loops
- Analog I/O blocks can be scaled to engineering units
- Analog blocks support single-transfer or block-transfer communication modes

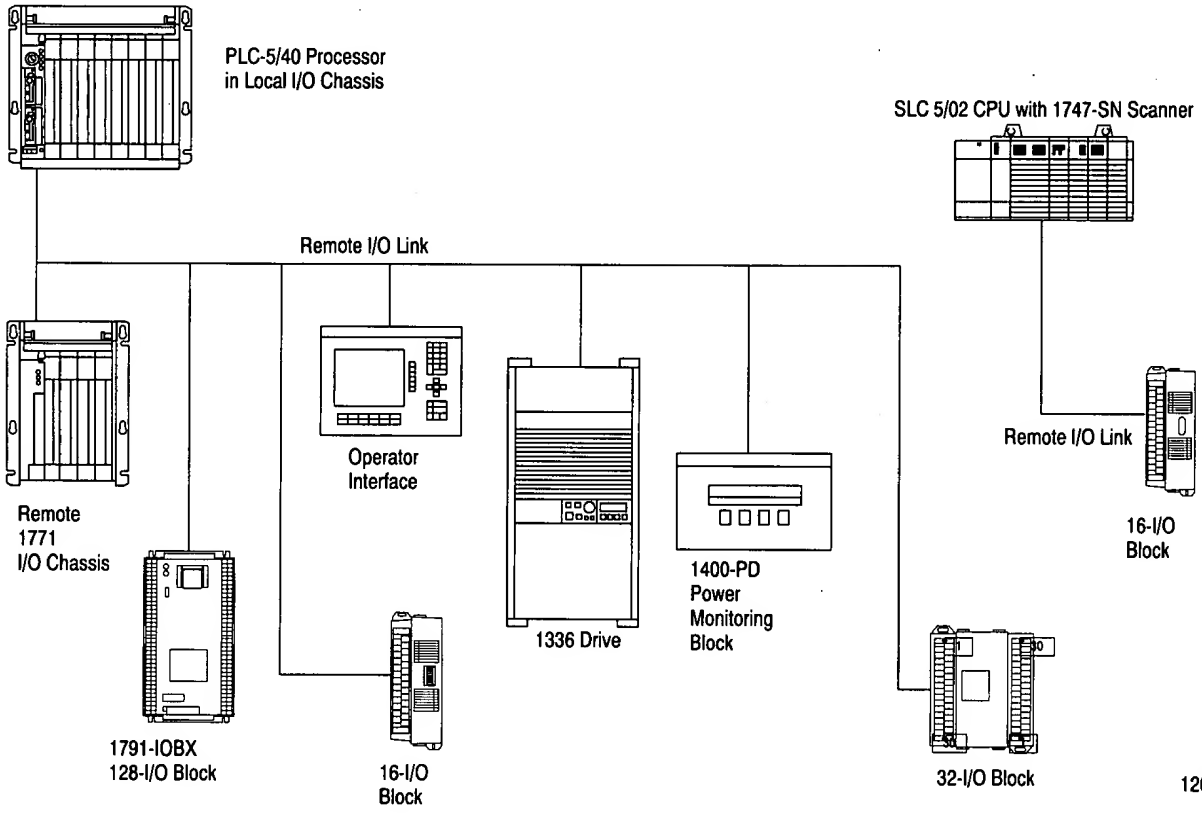
Dimensions

Block with 16 digital I/O or 6 analog I/O	177H x 69W x 98D mm (7.0H x 2.7W x 3.9D in)
Block with 32 digital I/O	177H x 111W x 98D mm (7.0H x 4.4W x 3.9D in)
Block with 32 inputs and 32 outputs (digital)	178H x 156W x 48D mm (7.0H x 6.1W x 1.9D in)
Block with 64 inputs and 64 outputs (digital)	334H x 156W x 48D mm (13.0H x 6.1W x 1.9D in)

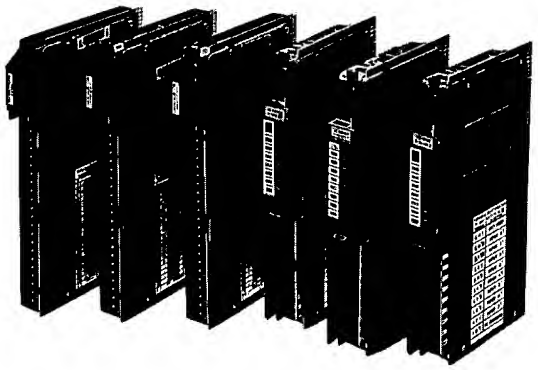
Specifications

See page 3-34 for I/O block specifications.

Typical Configurations



1771 Discrete I/O Modules



Discrete I/O modules have digital I/O circuits that interface to on/off sensors, such as pushbutton and limit switches, and actuators, such as motor starters, pilot lights, and annunciators. These outputs are discretely controlled by the state of corresponding bits in the PLC data table. These inputs discretely control the state of corresponding bits in the PLC data table

The 1771 family of I/O modules covers electrical ranges from 10 through 276V ac or dc; relay contact ouput modules are available for ranges from 0 through 276V ac or 0 through 175V dc.

Isolated inputs and outputs can be used in applications, such as motor control centers where individual control transformers are used. 1771 I/O modules include electrical-optical isolation and filter circuitry for signal noise reduction. As a trouble-shooting aid, status indicators are provided on the front of modules to input or output and fuse blown status.

Features

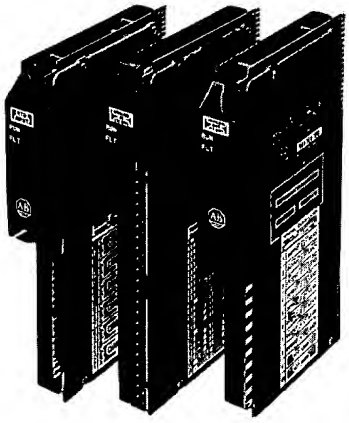
- No need to disconnect wiring to replace module
- Broad range of signal interfaces to ac and dc sensors/actuators for a wide variety of applications
- LED indicators show input/output status for easier troubleshooting
- Solid state outputs are fused for module-circuit protection
- Modules available in different densities for up to 32 I/O for greater flexibility and cost savings

3

Specifications

For specifications and a complete list of 1771 discrete I/O modules, refer to the I/O selection chart that begins on page 3-37.

1771 Analog I/O Modules



Analog I/O modules perform the required A/D and D/A conversions to discretely interface analog signals to PLC data table values using 16-bit resolution.

Analog I/O can be user-configured for the desired fault-response state in the event that I/O communication is disrupted. This feature provides a safe reaction/response in case of a fault, limits the extent of faults, and provides a predictable fault response.

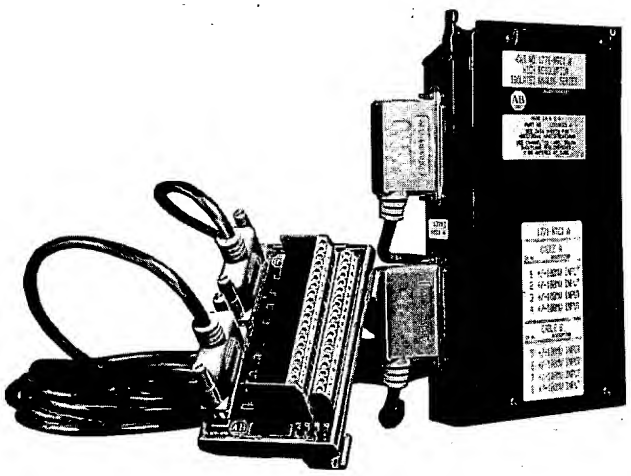
Features

- A wide range of signal levels including standard analog inputs and outputs, and direct thermocouple and RTD temperature inputs
- Software-selectable features include digital filtering for noisy transmitters and environments and range selection per I/O for added flexibility
- Comprehensive self-diagnostic tests: over/under range, high/low rate-of-change alarming, open input/open loop detection, on-board error checking
- Scaling to engineering units makes incoming signals easier to work with
- I/O chassis-supplier power eliminates the cost of external power supplies
- Inputs isolated from power-source noise
- Isolation between individual output circuits
- User-configurable output response (min, max, mid-range or last value) for safe reaction to a module fault
- A status block provides information to the processor for alarming and troubleshooting

Specifications

For specifications and a complete list of 1771 analog I/O modules, refer to the selection chart on page 3-40.

1771 N-Series Analog I/O Modules



The N-Series analog I/O modules offer connection points for analog transmitters/receivers at remote termination panels, current inputs with individual embedded 24V dc loop power for analog transmitters, and combinations of inputs and outputs in the same module. As with other analog I/O modules, they perform the required A/D and D/A conversions to discretely interface analog signals to PLC data table.

Features

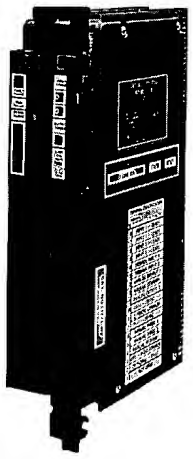
- High input (16-bit) and output (14-bit) resolution.
- Each input channel has scaling, out-of-range indication, high/low alarms with dead band, rate alarms, and digital filtering
- Each output channel has scaling, user-defined last state, high/low clamp limits, and rate-of-change limit
- High accuracy — 0.01% typical
- Loop power supplied for each module at individual current optional inputs for connection to transmitter — eliminates the need for external loop power supplies — enables isolation of current loops — greatly simplifies wiring of 2-wire transmitters — eliminates the need for fusing transmitters
- High isolation — 1000V isolation between channels
- Reliable design — no potentiometers, jumpers, switches, or single point of failure
- Simplified calibration — no hardware adjustments; module calibrated by its own firmware; calibration constants stored in nonvolatile memory
- Programmable application features — such as, scaling to engineering units; rate-of-change alarm; digital filtering; thermocouple/RTD linearization
- Remote termination panels (RTPs) — mount on asymmetrical #1 or symmetrical #3 DIN rails; pre-wiring reduces installation costs; optional fuses/resistors; user-defined termination flexibility; replace module without disturbing current loop

Specifications

For specifications and a complete list of 1771 N-series analog I/O modules, refer to the selection chart on page 3-41.

Proportional/Integral/Derivative Control (2-Loop) Module

(Cat. No. 1771-PD)



The 1771-PD module performs closed-loop PID control. It monitors the process variable, compares it with the desired setpoint, and calculates the required control-variable analog output based on its internal control algorithm. Use the PID module with a variety of analog actuators that operate in the 4 to 20mA or 1 to 5V dc range. The module can control one or two PID loops that can be independent or linked by cascading or decoupling.

Features

Input conditioning

- Read the process variable (PV) apply a normalized square root and digital filter
- Detect the loss of the PV

Control

- Select direct- or reverse-acting control
- Limit and/or set an alarm on the error signal
- Perform error dead band (zero crossing)
- Download a setpoint from the processor

Output conditioning

- Limit and/or set an alarm on the PID algorithm output
- Interface directly with a manual control station (bumpless transfer)
- Hold the PID algorithm output and/or the bias/feedforward output to independent loop tuning

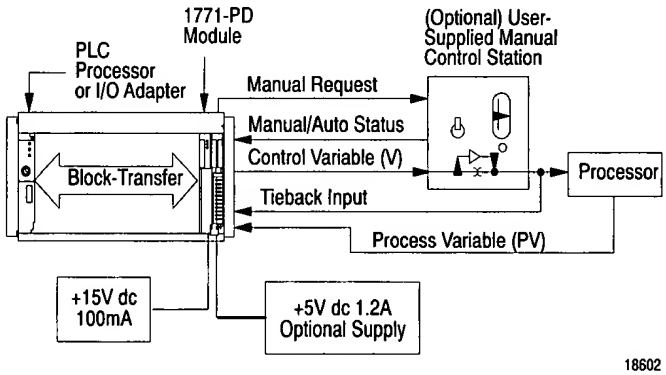
Expanded features

- Scale the PV, setpoint, and/or error
- Add a feedforward offset
- Perform lead/lag filtering on the feedforward term
- Cascade the output of loop 1 into the setpoint of loop 2

Specifications

Analog Inputs	
Number and type	• 2 Process Variable (Differential) • 2 Tieback (Single ended)
Range (selectable)	• 4-20 mA • 1-5V dc
Digital resolution	12-bit binary, 1 part in 4095
Accuracy	± 0.1% of range at 25°C
Digital Inputs	
Number and type	2 inputs for MAN/AUTO status
Analog Outputs	
Number and type	2 Control Variable (Single ended)
Range (selectable)	• 4-20mA • 1-5V dc
Digital resolution	12-bit binary, 1 part in 4095
Accuracy	±0.1% of range at 25°C
Contact Output for Manual Control Station	
Number and type	1 normally closed contact, held open
Power Requirements	
Backplane (or external 5V dc) current requirement	1.2A
External 15V dc	• 100mA at +15V dc • 100mA at -15V dc
Loop update time	100ms

Typical Configuration



Sub I/O Scanner Module

(Cat. No. 1771-SN)

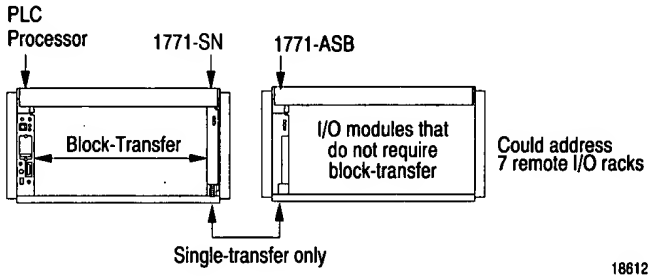
The Sub I/O Scanner Module lets a local PLC processor communicate with up to seven remote I/O racks, allowing you to expand a local system to include up to 896 additional remote I/O that do not require block-transfer. The I/O scanning operation of this module is similar to single-channel operation of a 1772-SD2 remote I/O scanner/distribution panel of a PLC-2/30 processor. However, the Sub I/O Scanner Module can not block-transfer I/O data to/from remote I/O chassis.

Specifications

Hazardous

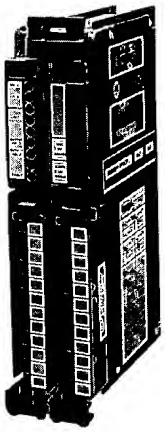
I/O configuration	Maximum of 7 remote I/O racks
Response time	• 15ms module throughout • Approximately 128ms between sensing an input and changing an output with block-transfer
Backplane current load	1.2A
Remote-I/O-link maximum cable length and transmission rate	• 10,000 ft @ 57.6k bit/s • 5,000 ft @ 115.2k bit/s

Typical Configuration



Encoder/Counter Module

(Cat. Nos. 1771-IJ, -IK)



The Encoder/Counter Module provides a high-speed counter that responds directly to input pulses sensed at the module's input terminals. The module accepts input pulses in either dual-channel quadrature form from an incremental encoder or in-single-channel form from (for example) a high-speed optical-beam device.

The encoder/counter module is available in two versions:

- The 1771-IJ module has TTL-compatible inputs and outputs
- The 1771-IK module has 12 to 24V dc inputs and outputs

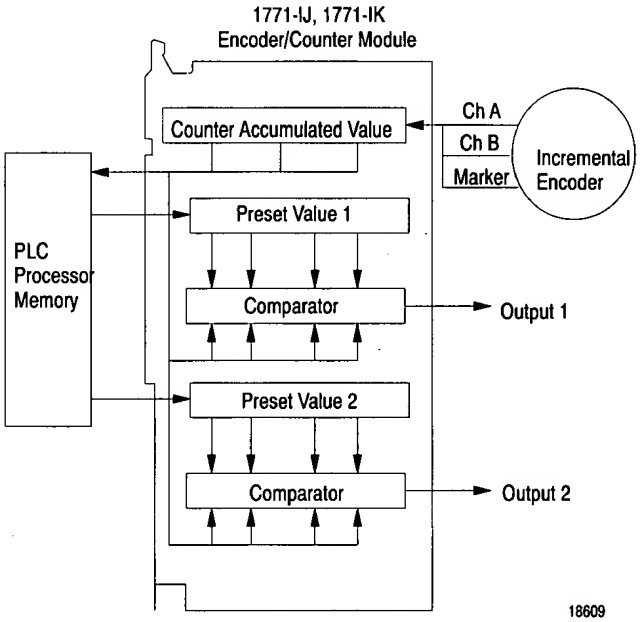
Features

- On-board counter assures that input pulse rate is not limited by either I/O scan or program scan
- Single- or dual-channel input provides compatibility with a variety of input devices
- Single-ended or differential input provides compatibility with a variety of input devices
- Two programmable on-board preset values enable comparison with accumulated values. This provides module output with fast response to position change
- Block-transfer of data for ease of programming

Specifications

Counters per module	1
Counter input (switch-selectable)	• Single channel • Dual channel
Input pulse rate	50kHz max
Data-transfer modes	• Single-transfer mode • Block-transfer mode
Backplane current load	1.4A
Electrical isolation	1500V rms (transient)
TTL input ratings (1771-IJ) (Bulletin 845N Incremental Encoder)	• Input current per channel: input device must be able to sink 16 mA. • Input voltage: VIH = 2.4V (min); VIL = 0.6V (max)
12-24V Input ratings (1771-IK)	• Input current per channel: input device must be able to sink 10 mA @ 12V or 20 mA @ 24V. • V input for 12V customer supply: High = 8.0V (min), Low = 4.0V (max) • V input for 24V customer supply: High = 16.0V (min), Low = 8.0V (max)
Output ratings	• Output current: I(max) = 500 mA sink per output (open-collector outputs without internal pull-up resistor) • Output voltage: V (output high) = 30.0 volts (max with external pull-up resistor); V (output low) 0.5V max at 500 mA
Wiring arm type	1771-WB

Logic Diagram



Real-Time Clock Module

(Cat. No. 1771-DC)

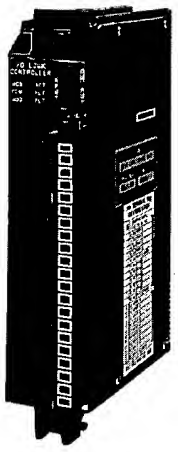
This module lets you read or set time and date information manually or by your processor's ladder-logic program. The module measures time in milliseconds, stores time and date information, responds to read and write block-transfers from the PLC processor, and displays the time and date with its liquid-crystal display (LCD).

Specifications

Accuracy	• Total variation in time over the operating temperature range of 0 to 60°C is 60 s/month • Timing accuracy (independent of transfers): +0.25ms, -1.25ms
Backplane current load	350 mA
Back-up battery	• Voltage: 9V dc • Current drain: 5 mA during a power outage • Life: One year standby when the module is powered. 48 hours during a power failure including 24 hours from battery low indication until the clock ceases.
Date and time functions	Day of the week, Year, Month, Day of the month, Hours, Minutes, Seconds
Control and reporting applications	Energy management, Process synchronization, Time and event correlation, Millisecond timing, Timing of power failures, Rate calculations

High-Speed Logic Controller Module

(Cat. No. 1771-DR)



This programmable module controls outputs based on the status of its inputs and according to its own internal logic without the delay of going through the I/O scan or PLC processor program scan. Its fast response time makes it ideal for high-speed sensing applications that include:

- distributed high-speed machine sequencing
- canning or bottling operations
- sorting materials on conveyers
- counting fast events over programmed time periods

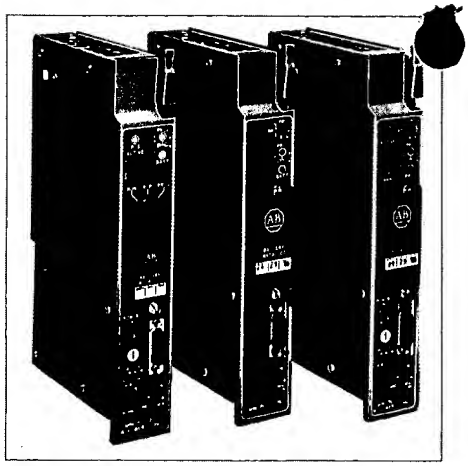
Features

- High-speed sensing makes the Logic Controller ideal for controlling high-speed events
- Block-transfer of commands, programmed inputs, programs, I/O status, accumulated values, detected programming errors, and self diagnositics to and from the processor

Specifications

Number and type of inputs	• 8 digital single-ended current sinking (source load) inputs
Number and type of outputs	• 4 digital single-ended current sourcing outputs
Input voltage range and logic state	• Logic 0: 0 to 4.0V dc • Logic 1: 10 to 24.0V dc
Output voltage range (user supply)	5 to 24V dc
Backplane current load	1.1 A
Input and output isolation	1500V dc
Response time	1 ms when input filter is 50 µs
Wiring arm	1771-WG

EXHIBIT C



Product Data

Allen-Bradley
Series C Mini-PLC-2/16, -2/17 Processors
(Cat. No. 1772-LX, -LXP, -LW, -LWP)
Series A Mini-PLC-2/02 Processor
(Cat. No. 1772-LZ, -LZP)

Processor Features

This product data explains the features and instruction sets of the Series A PLC-2/02 and Series C PLC-2/16 and PLC-2/17 processors. Unless stated otherwise, you may assume that the feature or instruction is common to all processors.

- 1K RAM in Mini-PLC-2/02
- 3K RAM in Mini-PLC-2/16
- 6K RAM in Mini-PLC-2/17
- up to 512 I/O capacity (with PLC-2/02 typically 128 I/O, PLC-2/16 typically 256 I/O, and PLC-2/17 a maximum of 512 I/O)
- memory protection above word address 177_8
- self-contained 120/220V AC power supply on processor (1772-LXP, -LWP, -LZP only) supplies an additional 4A to the backplane
- mode select key switch
- diagnostic indicators
- 8, 16 and 32 point I/O module capability
- basic instruction set
  - relay-like instructions
  - up to 296 timer and/or counter instructions (PLC-2/02)
  - up to 488 timer and/or counter instructions (PLC-2/16, -2/17)
  - program control instructions
  - data manipulation and comparison instructions
  - three digit math instructions (add, subtract, multiply, divide)

Publication 1772-2.27 — April 1988
Supersedes Publication 1772-2.27 — May 1987

PN 955104-06

839 ows.

- advanced instruction set:
  - jump instructions and subroutine programming
  - block transfer instructions
  - data-transfer file instructions
  - sequencer instructions
  - bit shift register instructions
  - The PLC-2/02, PLC-2/16 and PLC-2/17 processors can perform: EAF functions (6 digit add, subtract, multiply and divide), square root, Binary/BCD conversions, FIFO Load and Unload, $\log_{10}$, sine, cosine
  - The PLC-2/17 can perform these additional functions: $\log_e$, $y^{\pm x}$ and $e^{\pm x}$, reciprocal of x, averaging, standard deviation, PID, wall clock and calendar

Special Features

- on-line data change
- on-line programming
- selectable timed interrupt enables recurring subroutine
- self-contained lithium battery for memory
- full I/O forcing when using a Series C 1770-T3 terminal
- data highway interface
- report generation

Description

The processors contain the central processing unit (CPU) and memory of the programmable controller system.

The processors examine the state of your input devices, process this data in accordance with the program you entered, and set bits in the data table to control your output devices.

The processors monitor the status of their own operation, data in memory, and the system power supply.

Orderly shutdown protects your equipment if a malfunction is detected. LED indicators show proper operation or malfunctions.

A typical programmable controller system includes:

- A Processor with an integral power supply or an external power supply.
- An I/O Chassis (cat. no. 1771-A1B, -A2B, -A3B, - A4B)
- I/O modules (full 8, 16 or 32-Point I/O module compatibility)

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- Up to two Power Supply Modules (cat. no. 1771-P3, -P4, or -P5) when using a processor without an internal power supply or one additional power supply when using a processor with an internal power supply.

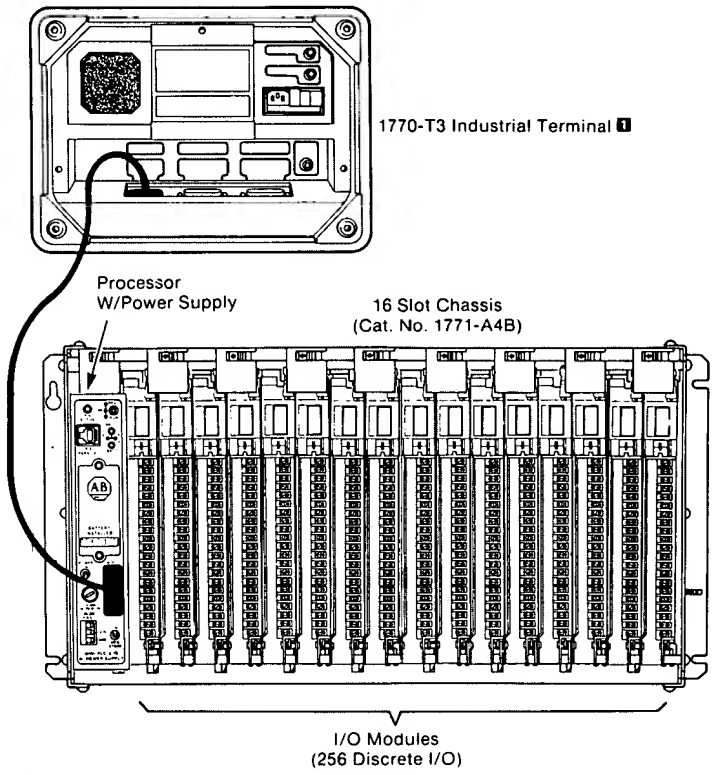
  The Auxiliary Power Supply (cat. no. 1771-P7) can be used with processors without an internal power supply.

- One Industrial Terminal (cat. no. 1770-T3) or IBM-compatible terminal with 6201 software to support programming, troubleshooting, and message display.

CAUTION: To prevent electrostatic damage, we construct, test, and pack our products in a static safe environment. When removing a product from a static-bag or disassembling a device, do so in a static safe environment.

A typical programmable controller system with 256 I/O capacity is shown in figure 1. The processor is always placed in the leftmost slot of an I/O chassis.

Figure 1
Programmable Controller System



1 Please refer to Compatibility-Industrial Terminal in this document

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Processors

Since the outward appearance of the PLC-2/02, PLC-2/16 and PLC-2/17 processors is nearly identical (the only difference is the catalog number across the bottom of the processor), we show an illustration of only one processor to make this data sheet easier to read and understand.

Functions of the status indicators, switches, connector ports and terminals are described in figure 2 for a processor without a power supply and in figure 3 for a processor with a power supply.

Figure 2
Without a Power Supply

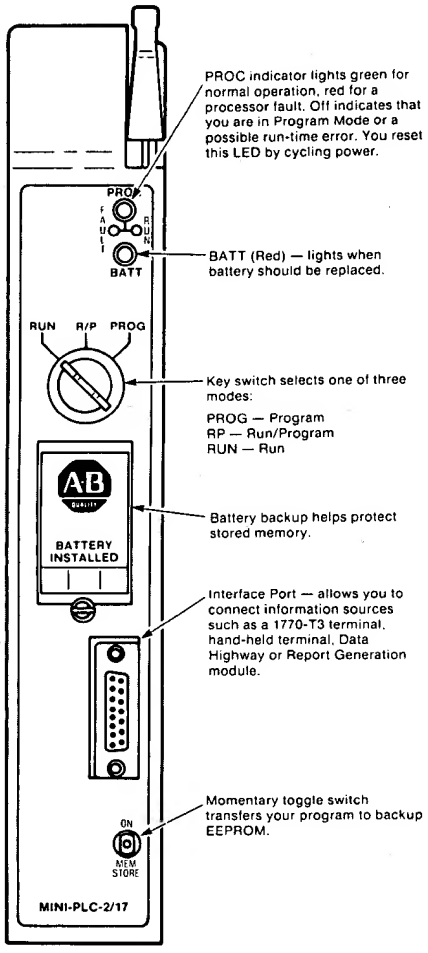

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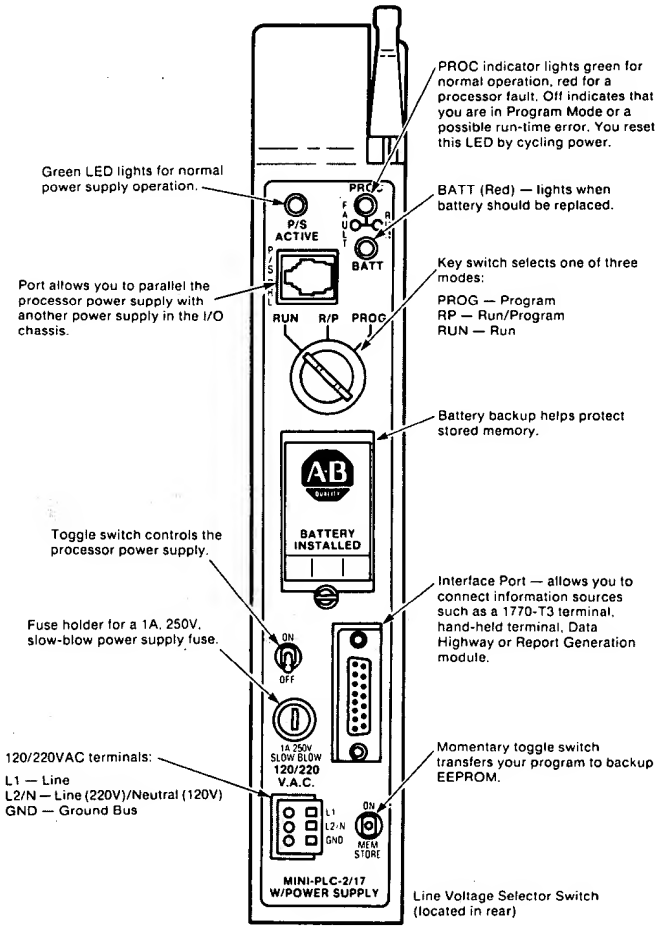
Figure 3
With a Power Supply



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Compatibility

All processors are compatible with other Allen-Bradley equipment subject to the following guidelines.

I/O Chassis

All processors are compatible with either the 1771-A1, -A2, -A3 or -A4 I/O chassis or the 1771-A1B, -A2B, -A3B or -A4B I/O chassis.

I/O Modules

All 1771 I/O modules (except as noted below) are compatible with these processors. To use a 16- or 32- point module with your processor you must use a 1771-A1B, -A2B -A3B, or -A4B I/O chassis.

Thermocouple Modules

For applications requiring a thermocouple module, you must use our 1771-IXE module. The 1771-IX Thermocouple module and the 1771-IY T/C Expander module are not compatible with these processors.

Power Supplies

The 1772-LZP (PLC-2/02), 1772-LXP (PLC-2/16), and 1771-LWP (PLC-2/17) processors contain an integral power supply that provides 5V DC @ 4A to the I/O chassis backplane. When additional backplane current is needed these processors can be paralleled with a 1771-P3 or 1771-P4 slot power supply. These power supplies protect the processor and I/O modules by shutting down when they detect an over or undervoltage, or an overcurrent condition. However, these processors cannot be paralleled with a second 1771-LZP, -LXP or -LWP processor or a 1771-P7 Auxiliary power supply.

The 1772-LZ (PLC-2/02), 1772-LX (PLC-2/16) and 1772-LW (PLC-2/17) processors do not contain an integral power supply. They can be powered by up to two 1771-P3, -P4 or -P5 power supplies, or a single 1771-P7 power supply.

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Industrial Terminal

We recommend that you program your PLC-2/02, PLC-2/16, or PLC-2/17 processors with a Series C, Revision B or later 1770-T3 terminal. Series A/Revision A of the 1770-T3 terminal is not compatible with the memory-protection feature of the PLC-2/02, PLC-2/16 or PLC-2/17 processors. You can use a 1770-T1 or 1770-T2 industrial terminal to program the PLC-2/02, PLC-2/16 or PLC-2/17 processors. However, only instructions supported by these terminals can be programmed.

WARNING: Programs entered using a 1770-T3 terminal must not be edited with either a 1770-T1 or a 1770-T2 industrial terminal. Such editing could result in unexpected operation with possible damage to equipment and injury to personnel.

When using 1/2-slot or 1-slot addressing, we recommend that you use a Series C/Rev B 1770-T3 terminal to obtain full compatibility with the processor. With this model terminal, you can perform the following operations in racks 1 and 2 (1-slot addressing) or racks 1 through 4 (1/2-slot addressing):

- immediate I/O
- block transfer
- full forcing

You need a Series C/Rev B 1770-T3 terminal to program bit shift instructions and to support 1/2-slot addressing.

Modes of Operation

You can place the processor in any one of three modes of operation with the three-position key switch located on the front of the processor.

PROG — You can enter and edit your program from the 1770-T3 terminal or an IBM-compatible with 6201-PLC2A software. User program and I/O are not scanned and outputs are disabled when the switch is in this position. You cannot change to another mode of operation with the 1770-T3 terminal or an IBM-compatible with 6201-PLC2A software when the switch is in this position.

RUN — The processor scans and executes your program. You cannot change to another mode of operation with the 1770-T3 terminal or an IBM-compatible with 6201- PLC2A software when the switch is in this position.

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RP (Run/Program) — Your program is continuously being scanned and executed. You can:

- change the data table on-line,
- change programs on-line, and
- program an optional EEPROM module...

with a 1770-T3 terminal or an IBM-compatible with 6201-PLC2A software. This switch position also allows you to remotely change the processor mode of operation with a 1770-T3 terminal or an IBM-compatible with 6201-PLC2A software by using the [SEARCH] 59x commands. For example:

If you want this mode of operation	Press this key sequence
Remote Run/Program	[SEARCH] 590
Remote Test	[SEARCH] 591
Remote Program	[SEARCH] 592

The remote modes of operation function as follows:

- Remote Program — The processor stops scanning and executing its stored program and waits for commands from the programmer. If you have an optional EEPROM memory module, you must be in the remote program mode to transfer RAM memory contents to the EEPROM memory module. Refer to Memory Module Product Data (publication 1772-2.22) for details on memory transfer.
- Remote Run/Program — This is the normal mode of operation, where the program controls your outputs. You can edit your program and make on-line data changes in this mode.
- Remote Test — The inputs are scanned, the program with any selectable timed interrupts is executed but the outputs are disabled.

A program is a listing of:

- things to be done
- in the order they are to be done
- under what conditions they are to be done

You have four methods to enter a program:

- 6201, 6202, 6211, 6212 Programming software and an IBM-PC compatible terminal (such as the 1784-T50 or 1784-T45)
- a 1770-T3 terminal
- an EEPROM module
- a Data Cartridge Recorder (cat. no. 1770-SB)

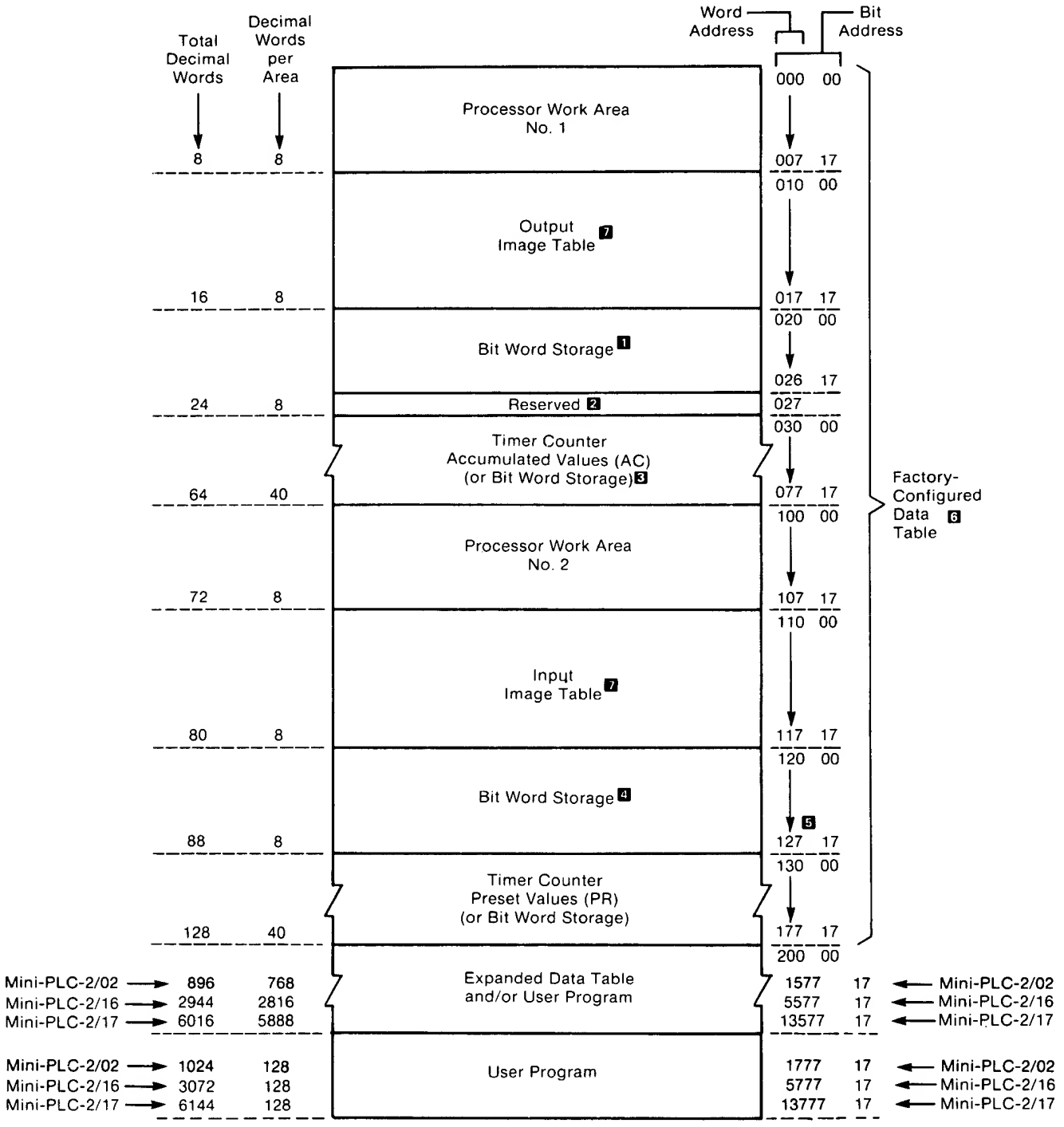
The 6200 industrial terminal software automatically displays program instructions in ladder diagram and functional block format.

Knowledge of the memory structure of the processor is helpful in understanding addressing and programming. Refer to:

- Factory Configured Data Table, for 2-slot addressing (figure 4) - Your processor is shipped with the data table configured for 128 words.
- Data Table Organization When Selecting 1-Slot Addressing (figure 5) - Output and input image table word addressing is assigned to Racks 1 and 2 when you have selected 1-slot addressing.
- Data Table Organization When Selecting 1/2-slot Addressing (figure 6) - Output and input image table word address is assigned to Racks 1, 2, 3 and 4 when you have selected 1/2-slot addressing.

Programming

Figure 4
Factory Configured Data Table



1 May not be used for accumulated values.

2 Not available for bit/word storage. Bits in this word are used by the processor.

3 Unused timer/counter memory words can reduce data table size and increase user program area.

4 May not be used for preset values.

5 Do not use word 127 for block transfer data storage.

6 Can be decreased to 48 words.

7 Do not use for bit/word storage.

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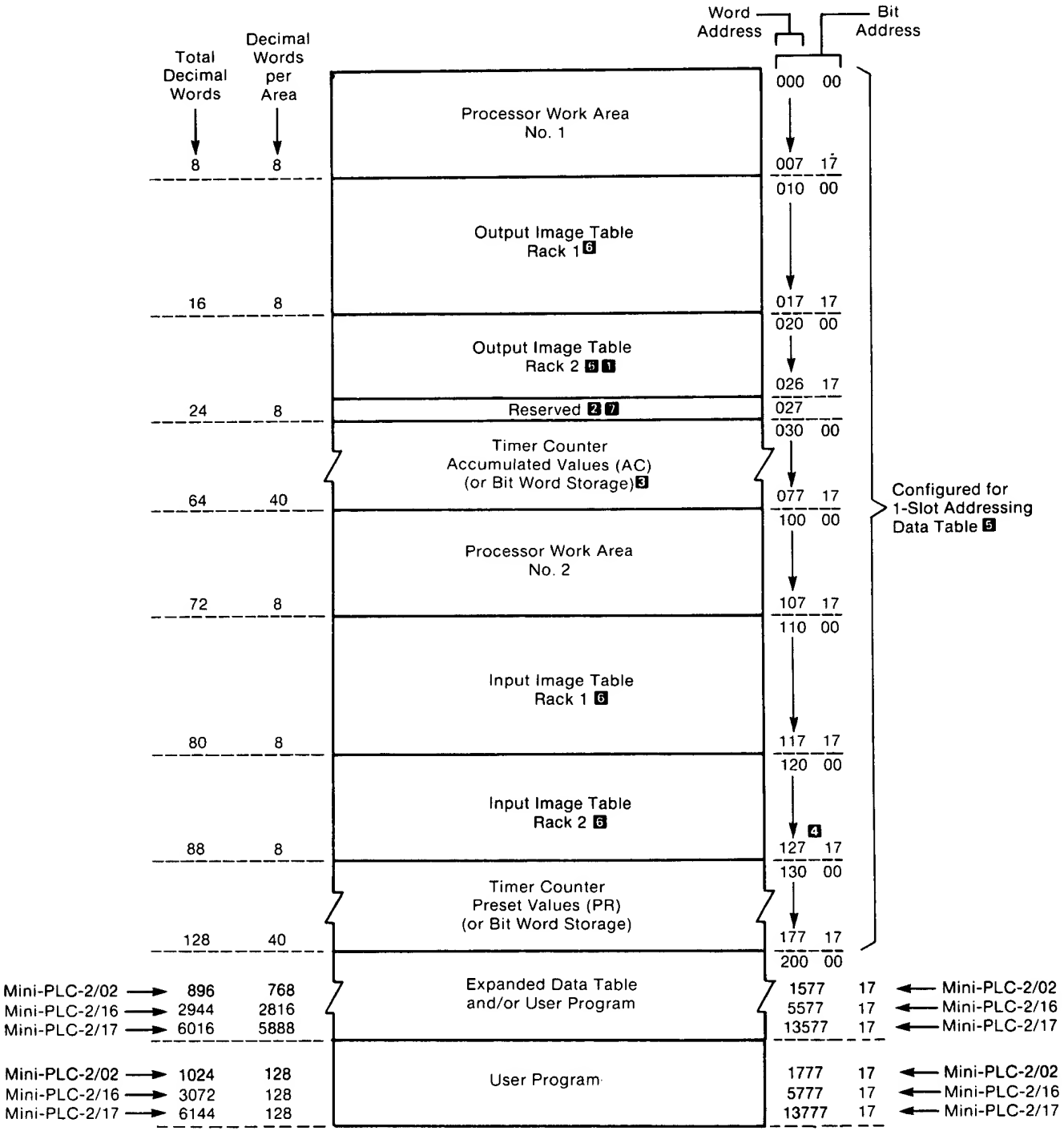
Figure 5
Data Table Organization When Selecting 1-Slot Addressing



1 May not be used for accumulated values.

2 Not available for bit/word storage. Bits in this word are used by the processor.

3 Unused timer/counter memory words can reduce data table size and increase user program area.

4 Do not use word 127 for block transfer data storage.

5 Can be decreased to 48 words.

6 Used with 1-slot addressing.

7 You cannot put an output or block transfer module in rack 2, I/O group 7 when using 1-slot addressing. You can put an input module in rack 2, I/O group 7.

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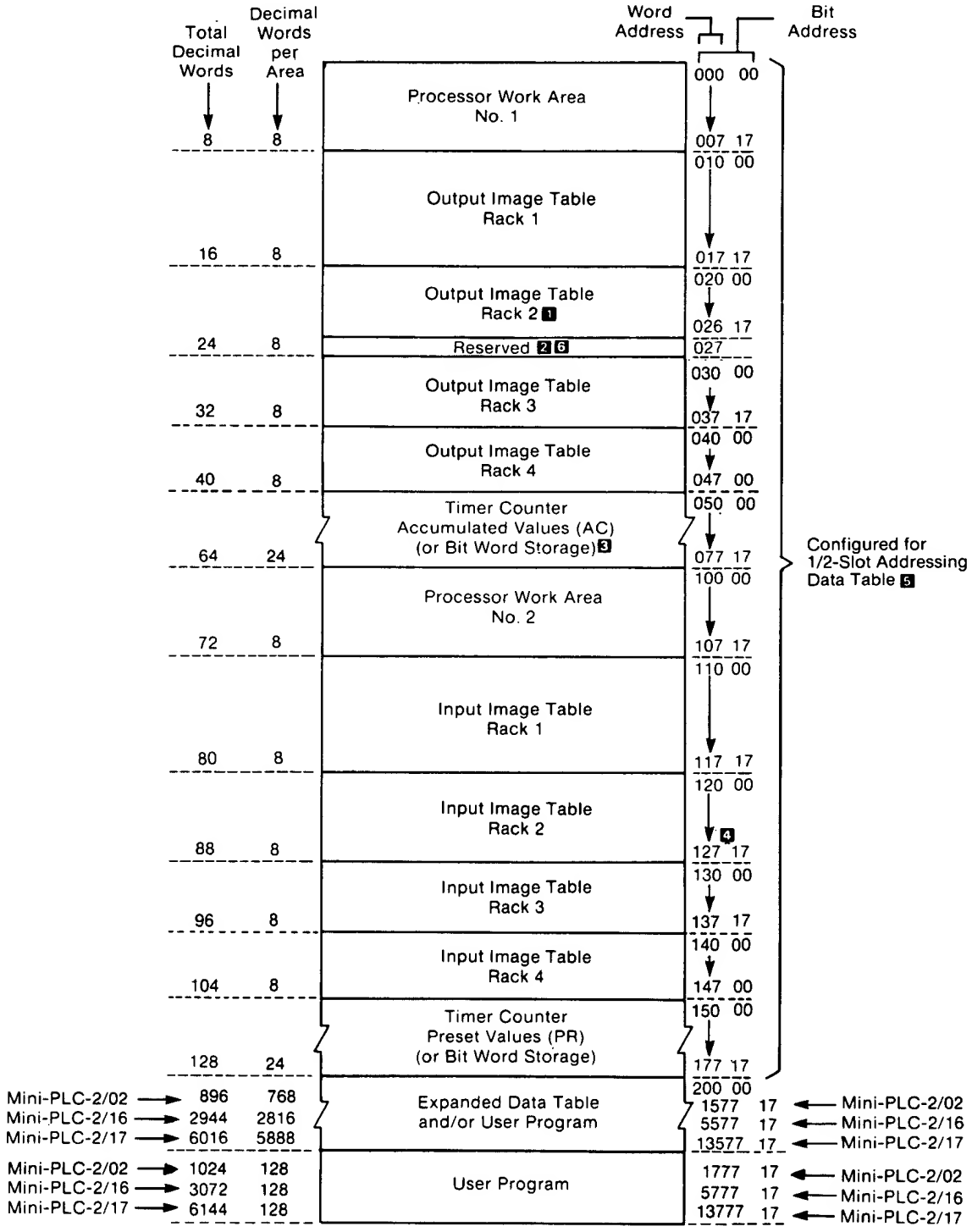
Figure 6
Data Table Organization When Selecting 1/2-Slot Addressing



1 May not be used for accumulated values.

2 Not available for bit/word storage. Bits in this word are used by the processor.

3 Unused timer/counter memory words can reduce data table size and increase user program area.

4 Do not use word 127 for block transfer data storage.

5 Can be decreased to 48 words.

6 You cannot put an output or block transfer module in rack 2, I/O group 7 when using 1/2-slot addressing. You can put an input module in rack 2, I/O group 7.

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Addressing

Addressing assigns one input and one output image table word to a location in the I/O chassis. The addressing mode and type of I/O module determines the total amount of I/O that can be addressed. Refer to the User's Manual (publication 1772-6.5.8) for details.

If you select:	and use:	you can address:
2-slot addressing	8-point I/O	up to 128 I/O
1-slot addressing	16-point I/O	up to 256 I/O
1/2-slot addressing	32-point I/O	up to 512 I/O

Basic Instruction Set

The basic instruction set includes:

- relay-like instructions
- timers and/or counters
- data manipulation and comparison
- three digit math (add, subtract, multiply, divide)

Relay-like Instructions

Relay-like instructions allow the processor to perform functions similar to those available with hard-wired relays.

Instruction Name	1770-T3 Display	Instruction Name	1770-T3 Display
Examine on	-| |-	Unlatch	-(U)-
Examine off	-|/|-	Branch start	
Energize	-( )-	Branch end	
Latch	-(L)-		

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Manual Name: SIMATIC TI505 Analog I/O Modules User Manual **Edition:** Second
Manual Assembly Number: 2586546-0072 **Date:** 12/92
Order Number: PPX:505–8120–2

Table B-3 Analog Output Module PPX:505–6208A Electrical Specifications

Output channels	8, single-ended, simultaneous voltage and current
Module width	Single-wide
Signal range	0 to 10 VDC, 0 to 20 mA
Voltage accuracy	(±)1.45% of full scale over full temp. range (±)0.5% of full scale at 25°C
Current accuracy	(±)1.83% of full scale over full temp.range (±)0.5% of full scale at 25°C
Temperature coefficient Voltage output Current output	 136 ppm/°C 204 ppm/°C
Digital-to-analog conversion	12 bits
Resolution (output)	12 bits, 2.5 mV, 5 μA
Update time	29 ms (min), controller scan time + 56 ms (max)
Module response time	27 ms (min), 54 ms (max)
Settling time	Current: 2.0 ms (max); Voltage: 0.2 ms (max)
Overshoot	50 mV typical
Load resistance Voltage Current	 5000 Ω min; no max 10 Ω min; 600 Ω max (600 Ω min, 1000 Ω max if extra 10-V power supply present in circuit)
Capacitance load (voltage outputs)	100 pF max
Inductive load (current outputs)	1.0 mH max
Module power from base	2.0 W max, 1.0 W typical
User power supply	20 to 28 VDC at 0.5 A with maximum ripple ±0.4 VDC, UL Class 2 power supply
Power supply protection	Overvoltage to 30 VDC, reverse voltage protected
Output signal wiring	Shielded, twisted-pair cable (14–24 AWG or 0.18–1.5 mm^2, stranded or solid)

Table B-2 Analog Input Module PPX:505-6108A Electrical Specifications

Number of input points	8, single-ended
Module width	Single-wide
Signal range (selected voltage range applies to all channels)	–5 V to +5 V and 0 to 20 mA, or –10 V to +10 V
Voltage accuracy	(±) 0.82% of full scale over operating range (±) 0.5% of full scale at 25°C
Current accuracy	(±) 1.25% of full scale over operating range (±) 0.7% of full scale at 25°C
Temperature coefficient Voltage input Current input	 58 ppm/°C 83 ppm/°C
Repeatability	(±) 0.1% of full scale over operating range
Resolution (input)	12 bits plus sign, 1.25 mV or 5 μA (±5 V range)
Analog-to-digital conversion	12 bits plus sign
Conversion method	Dual slope integration
Input system conversion time delay	330 ms max
Update time	250 ms max (for all channels)
Sample repetition time	250 ms max
Input filter delay time	75 ms typical
DC input resistance	1M Ω min with ±5 V range selected 500k Ω min with ±10 V range selected
Input protection Voltage Current	 Overvoltage to ±30 VDC Overcurrent to 30 mA
Type of protection	clamp diodes, optical isolation
Module power from base	4 W max, 2.5 W typical
User power requirements	None
Input signal wiring	Shielded, twisted-pair cable (14–24 AWG or 0.18–1.5 mm^2, stranded or solid)

Appendix B
Specifications

Table B-1 Environmental Specifications: Analog Input and Output Modules

Minimum torque for bezel screws	2.6 in-lb (0.3N-m)
Maximum torque for bezel screws	4.12 in-lb (0.6N-m)
Operating temperature	0 to 60° C (32 to 140° F)
Storage temperature	–40 to +70° C (–40 to 158° F)
Relative humidity	5% to 95% noncondensing
Pollution degree	2, IEC 664, 664A
Vibration	Sinusoidal IEC 68-2-6, Test Fc 0.15 mm peak-to-peak, 10–57 Hz; 1.0 g, 57–150Hz Random IEC 68-2-34, Test Fdc, equivalent to NAVMAT P–9492 0.04 g^2/Hz, 80–350 Hz
Electrostatic discharge	IEC 801, Part 2, Level 4, (15k V)
Shock	IEC 68-2-27; Test Ea
Noise immunity, conducted on Series 505 power supply and output module user power supply	IEC 801, Part 4, Level 3 IEC255–4 Appendix E EEC 4517/79 Com(78) 766 Final Part 4 MIL STD 461B CS01, CS02 and CS06
Noise immunity, radiated	IEC 801, Part 3, Level 3, MIL STD 461B RS01 and RS02
Isolation, field to controller	1500 Vrms
Corrosion protection	All parts of corrosion-resistant material or plated or painted as corrosion protection

NOTE: Variation in readings of up to 100% of full scale may occur during electromagnetic interference (EMI).

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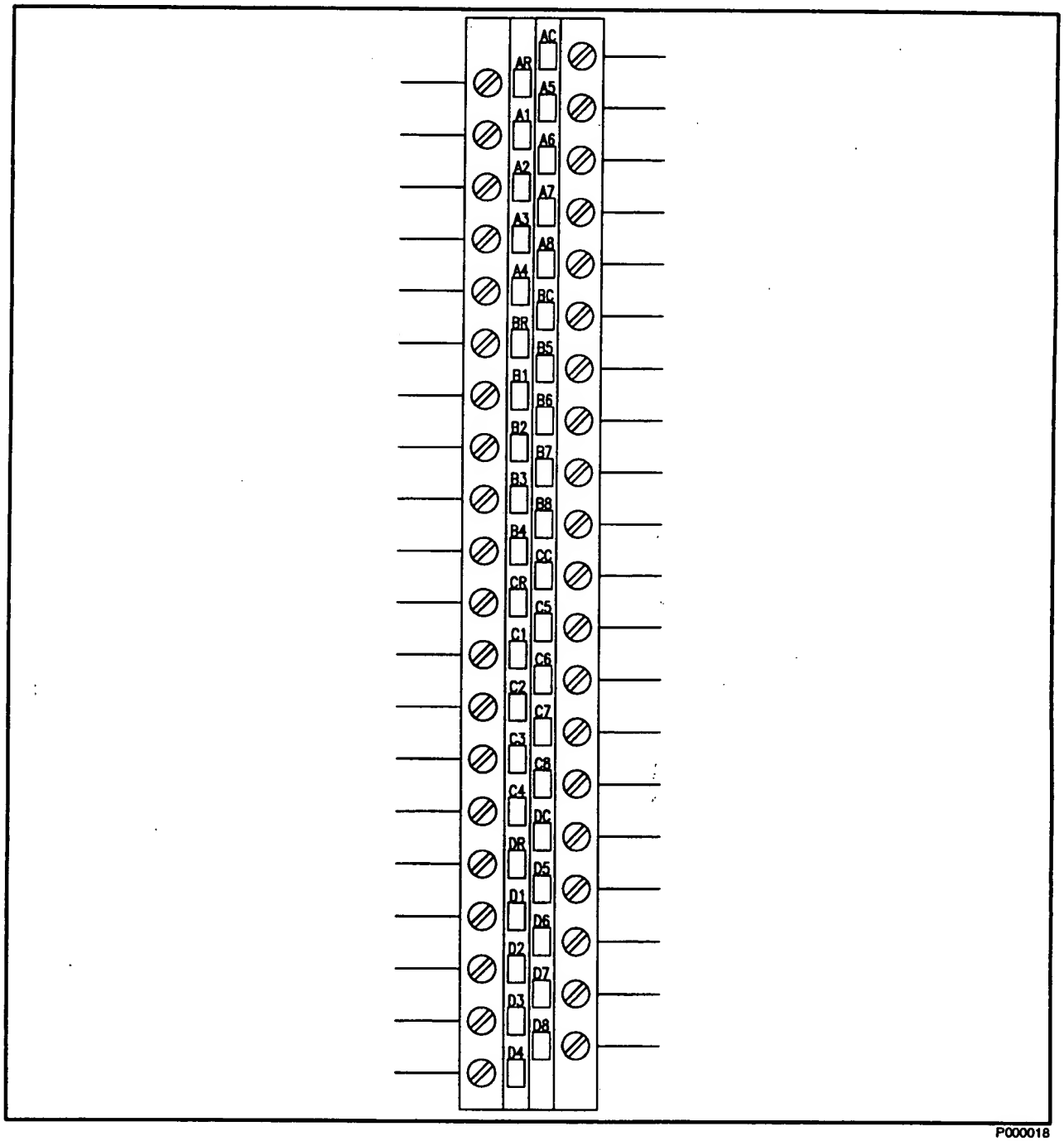
Appendix A
Terminal Block Worksheet



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Timer and Counter Instructions

You can set the time base of timers to 1 second, 0.1 second or 0.01 second increments. Each timer can time up to 999 increments. For timing beyond 999 increments, you can cascade timers. Each counter can count 999 increments.

Instruction Name	1770-T3 Display	Instruction Name	1770-T3 Display
Timer on-delay	-(TON)-	Count up	-(CTU)-
Timer off-delay	-(TOF)-	Count down	-(CTD)-
Retentive timer	-(RTD)-	Counter reset	-(CTR)-
Retentive timer reset	-(RTR)-		

Program Control Instructions

Output override or zone type instructions operate like a hardwired master control relay in that they can affect a group of outputs in your program. But, these instructions are not a substitute for a hardwired motor control relay which provides emergency I/O power shutdown.

Instruction Name	1770-T3 Display	Instruction Name	1770-T3 Display
Master Control Reset	-(MCR)-	Immediate Input	-(I)-
Zone Control	-(ZCL)-	Immediate Output	-(IOT)-
Last State			

Data Manipulation and Comparison Instructions

Data manipulation and comparison instructions access words or bytes in the data table. You can manipulate, transfer, or compare data. The results are available for program use. Such data may include:

- accumulated values of timers or counters
- values selected from within the program
- values from a thumbwheel switch or similar input device

Instruction Name	1770-T3 Display	Instruction Name	1770-T3 Display
Get	-[G]-	Less than	-[<]-
Get Byte	-[B]-	Equal to	-[=]-
Put	-(PUT)-	Limit test	-[L]-

Three-Digit Math Instructions

The processor performs four arithmetic operations (add, subtract, multiply and divide) on two values with up to three digits.

Instruction Name	1770-T3 Display	Instruction Name	1770-T3 Display
Add	-(+)-	Multiply	-(×)---(×)-
Subtract	-(-)-	Divide	-(÷)---(÷)-

Advanced Instruction Set

The advanced instruction set includes:

- EAF Functions
- jump instructions and subroutine programming
- block transfer
- data-transfer file instructions
- sequencer instructions
- bit shift registers

EAF Functions

A list of the EAF functions available in these processors is:

If you want to perform an operation of this type		Use this function number	If you want to perform an operation of this type	Use this function number
The Mini-PLC-2/02, Mini-PLC-2/16 and Mini-PLC-2/17 can perform these functions:			The Mini-PLC-2/17 can perform these additional functions:	
Addition	12-digit	(01)	Log_e	(31)
Subtraction	12-digit	(02)	Powers of Y $y^{\pm x}$	(33)
Multiplication	6-digit	(03)	Powers of e $e^{\pm x}$	(32)
Division	6-digit	(04)	Reciprocal 1/x	(34)
Square Root		(05)	Averaging	(06)
BCD to Binary		(13)	Standard Deviation	(07)
Binary to BCD		(14)	PID	(27)
FIFO Load		(28)	Set Clock	(10)
FIFO Unload		(29)	Set Date	(11)
Log_{10}		(30)	Set Leap Year and Day of the Week	(12)
Sin x		(35)		
Cos x		(36)	Read Clock	(15)
10^x		(37)	Read Date	(16)
			Read Leap Year and Day of the Week	(17)

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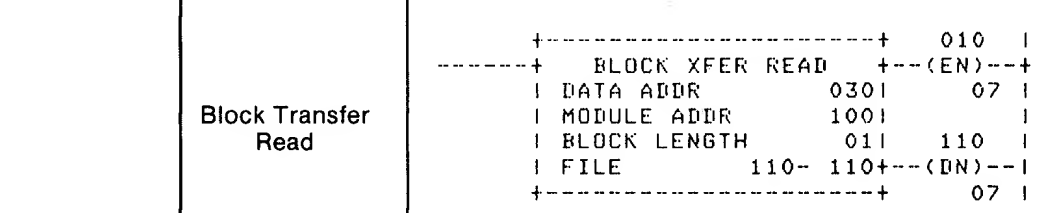
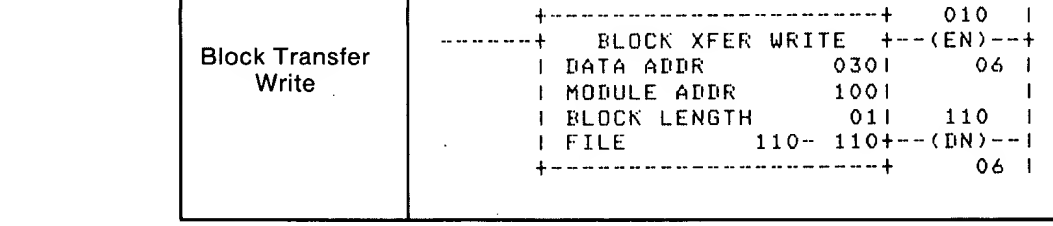
Jump Instructions and Subroutine Programming

Jump and subroutine instructions direct the processor to deviate from the sequential scanning of rungs. Such instructions and their displays are:

Instruction Name	1770-T3 Display	Instruction Name	1770-T3 Display
Jump	-(JMP)-	Label	-|LBL|-
Jump to subroutine	-(JSR)-	Return	-(RET)-

Block Transfer Instructions

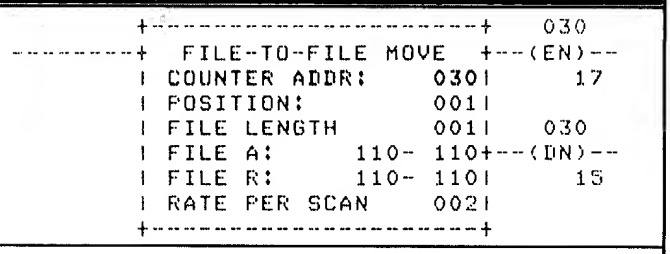
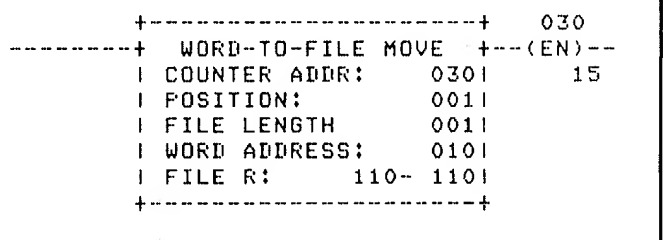
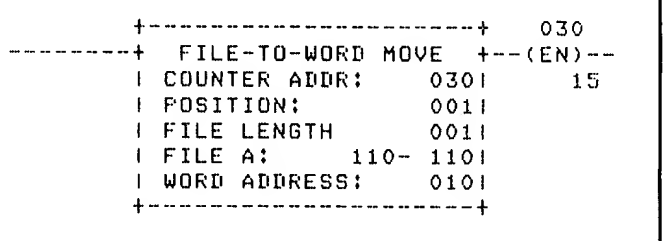
Block-transfer instructions transfer up to 64 words at a time between the processor data table and intelligent I/O modules.

Instruction Name	1770-T3 Display
Block Transfer Read	
Block Transfer Write	

You can use either instruction for transferring data in one direction, or you can use them in pairs for bidirectional communication.

Data Transfer File Instructions

File move instructions organize adjacent words into files of up to 999 words.

Instruction Name	1770-T3 Display
File to File Move	
Word to File Move	
File to Word Move	

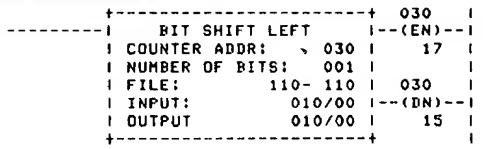
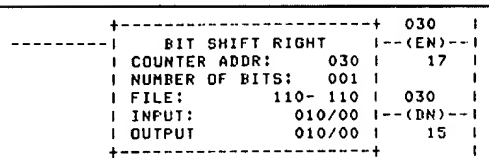
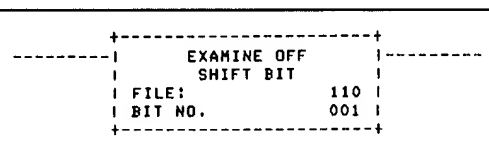
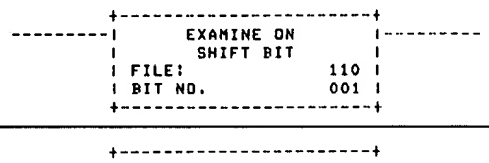
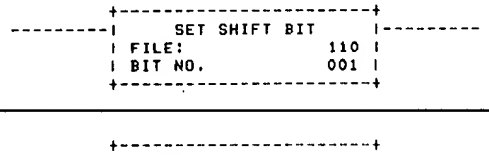
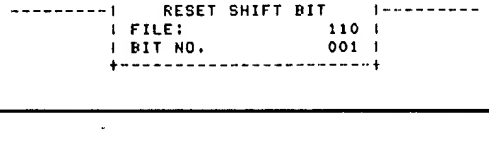
Sequencer Instructions

Sequencer instructions manipulate the status of up to four data table bits (up to four data table words) with each step of the instruction. The instruction steps to the next step with each false-to-true transition of the rung condition. You can designate up to a maximum of 999 steps per sequencer instruction.

Instruction Name	1770-T3 Display
Sequencer Output	+----------------------+ 030 ----------+ SEQUENCER OUTPUT +--(EN)-- | COUNTER ADDR: 030| 17 | CURRENT STEP: 001| | SEQ LENGTH: 001| 030 | WORDS PER STEP: 1+--(DN)-- | FILE: 110- 110| 15 | MASK: 010- 010| +----------------------+ | OUTPUT WORDS | | 1: 010 2: | | 3: 4: | +----------------------+
Sequencer Input	+----------------------+ ----------+ SEQUENCER INPUT +---------- | COUNTER ADDR: 030| | CURRENT STEP: 000| | SEQ LENGTH: 001| | WORDS PER STEP: 1| | FILE: 110- 110| | MASK: 010- 010| +----------------------+ | INPUT WORDS | | 1: 010 2: | | 3: 4: | +----------------------+
Sequencer Load	+----------------------+ 030 ----------+ SEQUENCER LOAD +--(EN)-- | COUNTER ADDR: 030| 17 | CURRENT STEP: 000| | SEQ LENGTH: 001| 030 | WORDS PER STEP: 1+--(DN)-- | FILE: 110- 110| 15 +----------------------+ | OUTPUT WORDS | | 1: 010 2: | | 3: 4: | +----------------------+

Bit Shift Register Instructions

You can use bit shift register instructions (bit shifts to move one bit left or right, examine on, examine off and set or reset a bit.

Instruction Name	1770-T3 Display
Bit Shift Left	
Bit Shift Right	
Examine Off Shift Bit	
Examine On Shift Bit	
Set Shift Bit	
Reset Shift Bit	

Programming and Hardware Features

The processors have the following programming and hardware features.

On-line Data and Programming Change

This feature lets you change data table values associated with instructions while the processor is executing your program in the run/program mode. You can also change your program in this mode.

Selectable Timed Interrupt

This processor function enables a user specified subroutine to recur at a user-specified interval. You can set the timed interval between successive executions of the subroutine to any whole number from 1 to 10 ms, 20 or 50 ms. Your program can change the timed interval and you can design the subroutine according to your programming needs. The processor:

- interrupts the program scan or I/O scan
- jumps to the subroutine
- executes the subroutine and returns to the program once every selected interval

If the processor detects that the execution time of the selectable timed interrupt subroutine exceeds a predetermined time interval, the processor sets status bit 027/02. This bit is available for your use and can be used to initiate annunciators or status indicators. The bit functions like a latch instruction and must be reset. The processor does not fault if this bit is set.

Selectable timed interrupts are inhibited while the processor is performing block transfers, and while you are programming on-line.

Battery Backup

A self-contained lithium battery provides battery backup for processor memory. The battery maintains memory for one and one-half years in the absence of AC power. The battery guards against loss of memory should AC power fail or the power supply shuts down. You can remove the processor from the I/O chassis without loss of memory.

A red battery-low indicator (labeled BATT), on the front of the module, lights when the battery is low.

EEPROM Backup

The optional EEPROM Memory Module (cat. no. 1772-MJ for the PLC-2/02 and PLC-2/16, and cat. no. 1785-MJ for the PLC-2/17) is available to back up memory. You can select one of three modes of transferring memory from the EEPROM to the processor's CMOS RAM. The EEPROM:

- transfers only if CMOS RAM is invalid
- transfers automatically to CMOS RAM
- does not transfer to CMOS RAM

The processor sets status bit 027/01 when it detects that backup EEPROM was transferred at power-up. This bit is available for your use and can be used to initiate annunciators or status indicators. The bit functions like a latch instruction and must be reset.

You can also store a program in an EEPROM module and download the program into processor memory instead of using the Data Cartridge Recorder (cat. no. 1770-SB).

Memory Protection

You can enable or inhibit memory protection by setting switch no. 8 of the switch assembly located behind the processor on the backplane of the I/O chassis. Setting this switch guards against changes to:

- data table values above address 177_8
- user program, subroutines, and messages

Full I/O Forcing

With 2-slot addressing, you can use full I/O forcing on all addresses. With 1-slot addressing, you can use full I/O forcing on Rack 2 as well as Rack 1 addresses if you have a Series C, Revision A 1770-T3 terminal. With Series B 1770-T3 terminals, you can do full I/O forcing on Rack 1 only. With 1/2-slot addressing you can use full I/O forcing on Racks 3 and 4 as well as racks 1 and 2 if you have a Series C, Revision B 1770-T3 terminal.

Input forcing allows you to set or reset any bit(s) in the input image table to simulate the action of an input device. Output forcing allows the output module to control the corresponding output device addressed to that bit regardless of how the program sets or resets the bit at that address.

This feature is useful when you troubleshoot and debug application programs.

Data Highway Interface

Data highway is a system that connects up to 64 intelligent devices on a single trunkline and allows them to communicate as peers. You can connect the PLC- 2/02, PLC-2/16, and PLC-2/17 processors to the data highway by using the Communication Adapter Module (cat. no. 1771-KA2) or the PLC-2 Family/RS-232-C Interface Module (cat. no. 1771-KG) with Communication Controller Module (cat. no. 1771-KE/KF)

You connect these devices to the network by droplines that can extend up to 100 feet from the 10,000 foot trunkline.

Report Generation

Reports depend on the support equipment used with your processor.

If you have this support equipment	You can store this number of messages
Cat. No. 1770-T1, -T2, or -T3 (Series A, Rev A) Industrial Terminal	6
Cat. No. 1770-T3 (Series A, Rev B or later) Industrial Terminal	70
Cat. No. 1770-RG Report Generation Module	198

Your ladder diagram program can initiate the display of any message by the push of a switch or by conditions you design into your program. Your messages can contain current data-table values, such as the status of a bit, byte, or word. You can display byte and word values in BCD. BCD values in your message can be data-table values manipulated by the processor, such as arithmetic manipulations, data comparisons, timer/counter accumulated values, or values obtained from intelligent input modules.

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Related Documentation

The following documents describe products used with your processor.

- Universal I/O Chassis (cat. no. 1771-A1B through -A4B) — publication 1771-2.49
- P3 Power Supply Module (cat. no. 1771-P3) — publication 1771-2.60
- P4 Power Supply Module (cat. no. 1771-P4) — publication 1771-2.61
- P5 Power Supply Module (cat. no. 1771-P5) — publication 1772-2.62
- P7 Power Supply (cat. no. 1771-P7) — publication 1772-2.93
- Industrial Terminal Systems (cat. no. 1770-T1, -T2, -T3) — publication 1770-6.5.3
- Report Generation Module (cat. no. 1770-RG) User's Manual — publication 1770-6.5.5
- RS-232/422 Interface Module (cat. no. 1770-KF2) User's Manual — publication 1770-6.5.13
- Communication Adapter Module (cat. no. 1771-KA2) User's Manual — publication 1771-6.5.1
- Communication Controller Module (cat. no. 1771-KE, -KF) User's Manual — publication 1771-6.5.15
- PLC-2 Family/RS-232 Interface Module (cat. no. 1771-KG) User's Manual — publication 1771-6.5.8
- PLC-2 Family SCADA Master User's Manual — publication 1771-6.5.39
- PLC-2 Family MODEM Interface Module (cat. no. 1779-KFL, -KFLR) User's Manual — publication 1771-6.5.33
- DHII Asynchronous Device Interface (cat. no. 1779-KFL, -KFLR) User's Manual — publication 1779-6.5.1
- DHII Synchronous Device (cat. no. 1779-KFM, -KFMR) User's Manual — publication 1779-6.5.2
- DHII PLC-2 Family Interface (cat. no. 1779-KP2, -KP2R) — publication 1779-6.5.3

Specifications

	Mini-PLC-2/16 Processor or Mini-PLC-2/02 Processor without a Power Supply	Mini-PLC-2/17 Processor without a Power Supply
Location	1771 I/O chassis left most slot	
Backplane Current	1.25A Requirement	
Battery Backup	Self-contained lithium battery maintains memory for 2-1/2 years with no AC applied to the processor	
Data Table Size	PLC-2/02: Floating, 48 to 896 words PLC-2/16: Floating, 48 to 2944 words	Floating: 48 to 6016 words
Memory Size	1024 (1K) PLC-2/02 3072 (3K) PLC-2/16 16-bit words RAM	6144 (6K) 16-bit words RAM
EEPROM (Optional)	3K, 1772-MJ	6K, 1785-MJ
I/O Scan	1.08 ms (2-slot addressing) 2.05 ms (1-slot addressing) 2.85 ms (1/2-slot addressing)	
Program Scan	12.5 ms/K (minimum) 20 ms (typical application program)	
I/O Compatibility	Bulletin 1771 I/O	
Mode Selection	Key switch on the front panel and from the keyboard of the 1770-T3 terminal	
Environmental Conditions **Operating Temperature** **Storage Temperature** **Relative Humidity**	 0 to 60° C (32 to 140° F) -40 to 85° C (-40 to 185° F) 5% to 95% (without condensation)	
Keying (top conector)	Between 46 and 48 Between 54 and 56	
	Mini-PLC-2/16 Processor or Mini-PLC-2/02 Processor with a Power Supply	**Mini-PLC-2/17 Processor with a Power Supply**
	These processors have the same features as those listed above but these also have a self-contained power supply.	
Input Voltage	120/220 V AC (switch selectable)	
Input Voltage Range	97 to 132V AC/194 to 264V AC	
Nominal Input Power	96VA	
Frequency	47 to 63 Hz	
Output Current to Backplane	4A	
Keying (top connector)	Between 46 and 48 Between 54 and 56	
Real Time Clock Accuracy		typically ±10 sec/day from 0 to 60° C (32 to 140° F)

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ALLEN-BRADLEY
A ROCKWELL INTERNATIONAL COMPANY

Programmable Controller Division
747 Alpha Drive, Cleveland, OH 44143

Publication 1772-2.27 — April 1988
Supersedes Publication 1772-2.27 — May 1987

PN 955104-06

EXHIBIT D

ML-C484-APL

Gould
484 Programmable Controller

APPLICATIONS MANUAL

GOULD
Electronics

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Preface

Manual Content

This manual contains instructions for installing, wiring, and calibrating the Analog Input Module (PPX:505–6108A) and the Analog Output Module (PPX:505–6208A). The modules operate with the Series 505™ controller.

The manual does not give the details of analog-to-digital conversion techniques. Familiarity with these techniques may be necessary in some applications.

References

Refer to the manuals listed below for instructions on installing, programming, and troubleshooting your System 505 controller.

- *SIMATIC® TI545™ System Manual* (2586546–0053)
- *SIMATIC® TI560T™/TI565T™ System Manual* (2597773-0035)
- *SIMATIC® TI505™ Programming Reference Manual* (2586546-0051)
- *SIMATIC® TI500™/TI505 TISOFT™ Release 4.2 User Manual* (2588081–0019)
- *TISOFT 1 and 2, Rel. 2.0 User Manual* (2600847-0001)

Agency Approvals

Series 505 Analog Input and Analog Output Modules meet standards of the following agencies:

- Underwriters Laboratories: UL® Listed (Industrial Control Equipment)
- Canadian Standards Association: CSA Certified (Process Control Equipment)
- Factory Mutual Approved; Class I, Div. 2 Hazardous Locations
- Verband Deutscher Elektrotechniker (VDE) 0160 Electrical Equipment (Self-Compliance)

Series 505 products have been developed with consideration of the draft standard of the International Electrotechnical Commission Committee proposed standard (IEC-65A/WG6) for programmable controllers.

Telephoning for Assistance

For technical assistance, contact your Siemens Industrial Automation, Inc. distributor. If you need assistance in contacting your distributor, call 1–800–964-4114.

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2-1 — 2-14	Second		
3-1 — 3-9	Second		
A-1	Second		
B-1 — B-3	Second		
Registration	Second		

MANUAL PUBLICATION HISTORY

SIMATIC TI505 Analog I/O Modules User Manual
Order Manual Number: PPX:505-8120-2

Refer to this history in all correspondence and/or discussion about this manual.

Event	Date	Description
Original Issue	10/91	Original Issue (2591824-0001)
Second Edition	12/92	Second Edition (2591824-0002)

SIEMENS

SIMATIC TI505

Analog I/O Modules

User Manual

Order Number: PPX:505-8120-2
Manual Assembly Number: 2586546-0072
Second Edition

$73

01/21/92

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Chapter 1
Product Overview

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1.1 Description

The Series 505 Analog Input and Output Modules (PPX:505–6108A and PPX:505–6208A) are single-wide versions of the Analog I/O Modules (PPX:505–6108 and PPX:505–6208), and can replace the double-wide models without any wiring changes. The Input Module (PPX:505–6108A) offers the additional benefit of an optional ±10 V input range, and it does not require external user-supplied power. The Output Module (PPX:505–6208A), like the double-wide PPX:505–6208, requires user-supplied 24 VDC power to maintain low power consumption from the base.

The Series 505 Analog I/O Modules (Figure 1-1) connect the controller with devices which monitor or control pressure, position, flow, temperature, or speed using voltage or current signals. The input module translates an analog input signal from a monitoring device into an equivalent digital word and transmits that data to the controller for processing. The output module translates a digital word from the controller into an equivalent analog signal and transmits that data to an output device that controls pressure, position, flow, temperature, or speed.

A Module Good LED on the front of each module indicates the status of the power, self-diagnostics, and the fuse (for the output module). Figure 1-1 shows the location of the Module Good LED indicator.

If the LED is on:

- System and user power are good
- Fuse is good
- Module has passed self-diagnostics

If the LED is off, one of the above has failed. See Chapter 3 for instructions on using the LED to troubleshoot.

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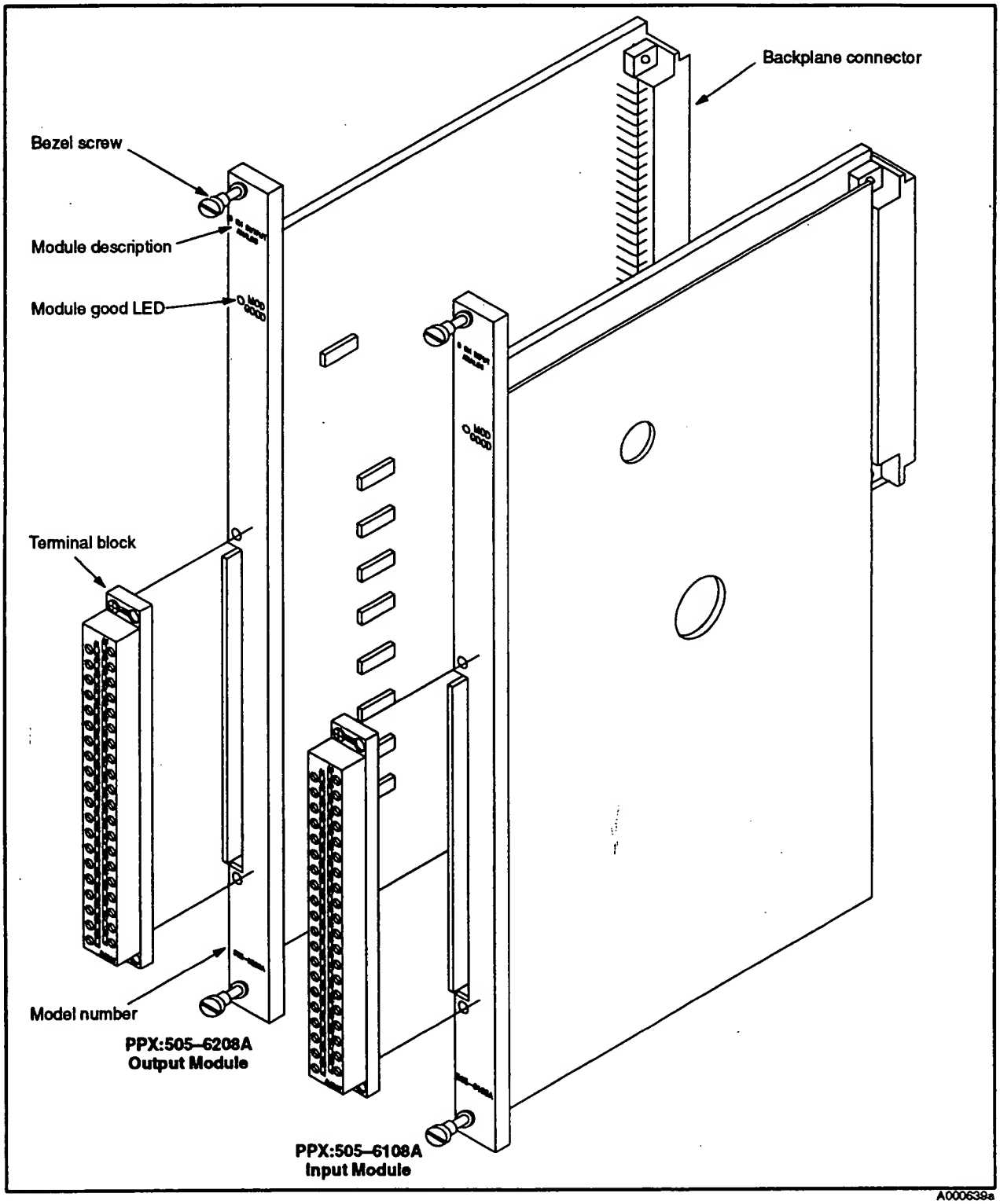

Figure 1-1 Series 505 Analog Modules

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1.2 Analog Input Operation

Signal Translation

The Analog Input module operates asynchronously with the controller. That is, the controller and module do not update at the same time. Instead, the module translates all analog inputs in one module update (<250 ms) and stores the translated words in buffer memory. When the controller I/O scan starts, it retrieves the words from the buffer memory of the module.

The analog signal is translated into a 12-bit digital word. Since the controller requires a 16-bit word for inputs, the 12-bit value from the converter is placed into a 16-bit word for transmittal to the controller. As shown in Figure 1-2, of the four bits not used for the converter magnitude, one is used to show the sign of the value, one is used to note overrange values, and the remaining two are not used and are set to zero.

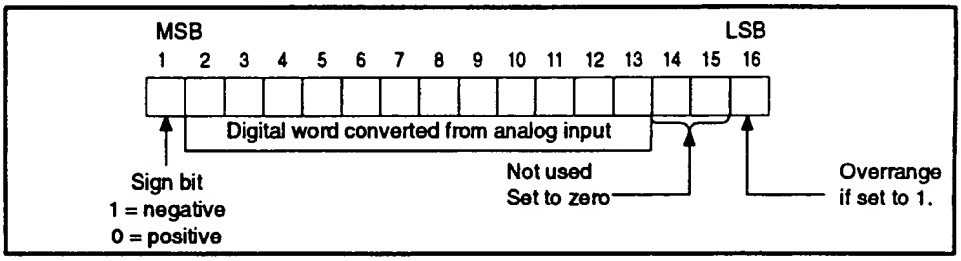

Figure 1-2 Output from the Module to the Controller

An overrange condition arises from an excessive voltage input, causing the digital word to be in excess of ±32000. Figure 1-3 shows the effects of excessive voltage. Values in parentheses apply to the ±10 V range.

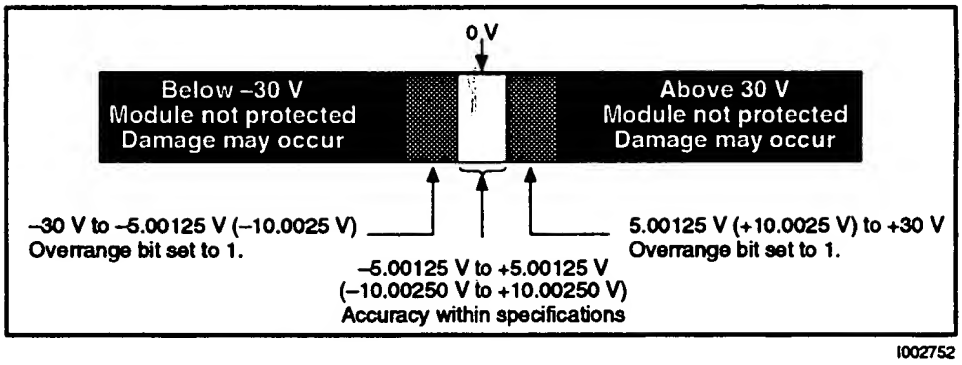

Figure 1-3 Effect of Voltage Input on the Module

Current or Voltage Input

The analog input module has eight inputs. You can select each of the eight inputs to receive either voltage or current as the incoming analog signal. Since the inputs are single-ended, the source for a current signal must be a true current-sourcing transmitter, not a current-sinking transmitter.

- For a voltage input, the incoming signal may range from –5 to +5 V, or from –10 to +10 V. The optional voltage input range of ±10 V is available via jumper selection on the circuit board. The voltage range selected applies to all eight input channels. Refer to Figure 3-2.
- For a current input, the incoming signal may range from 0 to 20 mA.

NOTE: The module is factory-calibrated and shipped configured for the ±5 V input range, which is required for current input using the internal sense resistors. If your application requires ±10 V, recalibrate the module with the ±10 V setting selected.

Choosing Resistors

The input module has eight (one per point) built-in, precision resistors (250 Ω, 0.1%). The resistor changes input current to voltage, which is what the module monitors internally. The built-in resistor allows a current range from 0 to 20 mA. You may use other external resistor values for other current ranges. If you install an external resistor, be sure that it meets the ±5 V input constraint and connects between Voltage In and Return for the selected channel. Follow proper safety guidelines when you install resistors. To determine the resistor needed, use the following equation.

$$Resistor\ needed\ (\Omega) = \frac{5\ V}{max\ current\ in\ amps}$$

Calculating Digital Words

The module has a resolution of 8 counts out of 32000. That is, the smallest unit into which the module divides a unipolar input is 1 part out of 4000. For a voltage input of 0 to +5 V, this division corresponds to a step of 1.25 mV. For a current input of 0 to 20 mA, a step of 5 µA can be resolved.

Use the following equations to calculate the digital word which results from a particular voltage or current input.

$$Digital\ word\ (WX) = \frac{Input\ voltage}{5\ V} \times 32000$$

$$Digital\ word\ (WX) = \frac{Input\ current\ (mA)}{20\ mA} \times 32000$$

If the module is set for ±10 V input range, each step of eight counts corresponds to an input voltage change of 2.5 mV, and the digital word is defined as follows:

$$Digital\ word\ (WX) = \frac{Input\ voltage}{10\ V} \times 32000$$

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1.3 Analog Output Operation

The Analog Output module operates synchronously with the controller. Any change in the output signal is dependent on the update time of the module. Figure 1-4 shows this relationship.

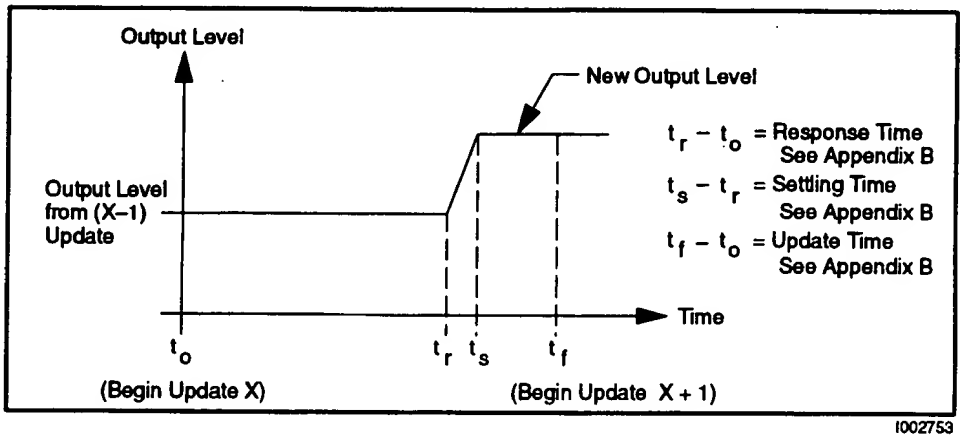

Figure 1-4 Relationship of Update Time to Change in Signal Output

The Analog Output module has eight channels, providing simultaneous voltage and current, ranging from 0 to 10 V and from 0 to 20 mA. Note that the current output is a sourcing type. Therefore, any shorts in the output circuit cause the output current to bypass the field device in the circuit.

The controller sends a 16-bit binary word to the module. Figure 1-5 shows the data word format. The digital value, which is translated into an analog output signal, occupies 12 of the 16 bits. The most significant bit (MSB) denotes the sign of a value. The remaining bits are unused.

NOTE: Bit 1 (the sign bit) is used to check for a negative number sent to the output module. If this bit is set to 1, the output for the point is not updated, and the last positive output is repeated.

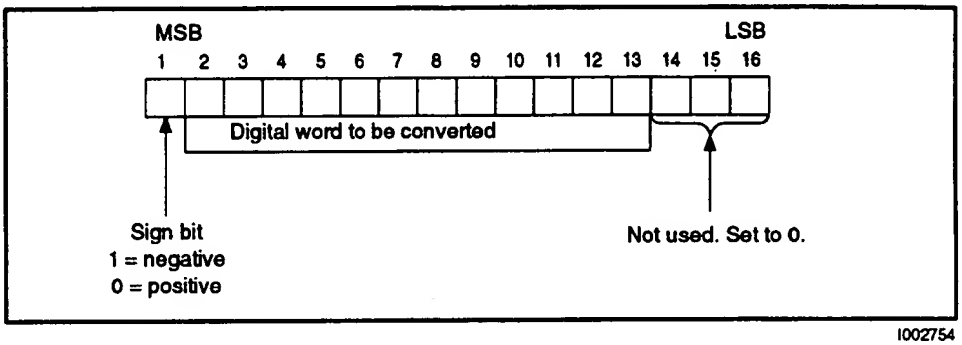

Figure 1-5 Output from Controller to Module

The resolution of the module is 8 counts out of 32000, regardless of whether the signal is used as voltage or current. Therefore, the smallest step unit for voltage is 2.5 mV and for current is 5 μA. To calculate the digital word necessary to achieve a certain output voltage or current, use the following equations.

$$Digital\ word\ (WY) = \frac{Desired\ output\ voltage}{10\ V} \times 32000$$

$$Digital\ word\ (WY) = \frac{Desired\ output\ current\ (mA)}{20\ mA} \times 32000$$

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1.4 Power Sources

The output module requires both user-supplied and base-supplied power.

Table 1-1 shows the input module response at power-up and power-down.

Table 1-1 Analog Input Module Power Cycling

Base Power	User Power	Module
Transition on	Not applicable	Module resumes converting and controller resumes reading from module
Transition off	Not applicable	Module and controller power down. All input data cleared

Table 1-2 shows the output module response at power up and power down.

Table 1-2 Analog Output Module Power Cycling

Base Power	User Power	Module
On	Transition off	Off—module sets fail bit
On	Transition on	Resumes prior state until next update
Transition off	On	Freezes last value
Transition on	On	Holds last value until next update
Off	Transition on	Off

Chapter 2
Installation

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2.1 Wiring Guidelines

Wiring for these modules consists of wiring for the input or output signal and wiring user power for the output module. Keep the two types of wiring separate to prevent noise on the signal wiring. Wiring for the input or output signal should be shielded, twisted-pair cable (14–24 AWG or 0.18–1.5 mm^2, either stranded or solid-type).

⚠WARNING **Use wires suitable for at least 75°C. Signal wiring connected to this module must be rated at least 300 V.**

⚠ATTENTION ***Employer des fils d'alimentation pour au moins 75°C. Le cablage de signalisation raccordé dans cette boîte doit convenir pour une tension nominale d'au moins 300 V.***

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Follow these guidelines when you wire the module.

- Use the shortest possible wires.
- Avoid placing signal wires parallel to high-energy wires. If the two must meet, cross them at right angles.
- Avoid placing wires on any vibrating surfaces.
- Avoid bending the wire into sharp angles.
- Use wireways for wire routing.

Terminate shielding for the input cable at the source end of the signal. This means that the point of origin of the input signal wire should be the shield termination point. If more convenient, you can terminate the shield to earth ground at the module using the two lower screws on the user wiring connector. Do not tie the shield to earth ground at both ends of the wiring; this practice may cause ground currents that could induce noise.

Terminate shielding for the output cable at the base, using the two lower screw terminals on the user wiring connector.

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2.2 Planning Analog Output Wiring

Signal Wire Carrying Current

Loop resistance for the output circuit is determined by the length and type of wire and the device series resistance. This section gives instructions for calculating the maximum length cable you can use. The circuit resistance must be in the range of 10–600 Ω. If you use a separate power supply of 10 V, the minimum resistance increases to 600 Ω, and the maximum resistance increases to 1000 Ω. To determine the resistance of a channel output loop, use the following equation.

$$Loop\ resistance = (2 \times CL \times RFT) + TFL$$

where
CL = cable length
RFT = conductor resistance (Ω/unit length)
TFL = sum of resistance for all field devices

The result of this equation must be less than 600 Ω. If the result is greater than 600 Ω but less than 1000 Ω, insert a 10 V power supply into the loop to maintain the accuracy of the module, or change one of the other loop resistance factors. Any value over 1000 Ω prevents the module from operating accurately. Figure 2-1 shows a schematic for wiring an output loop with a resistance of less than 600 Ω. Also shown in Figure 2-1 is a schematic for adding a power supply to allow loop resistance up to 1000 Ω.

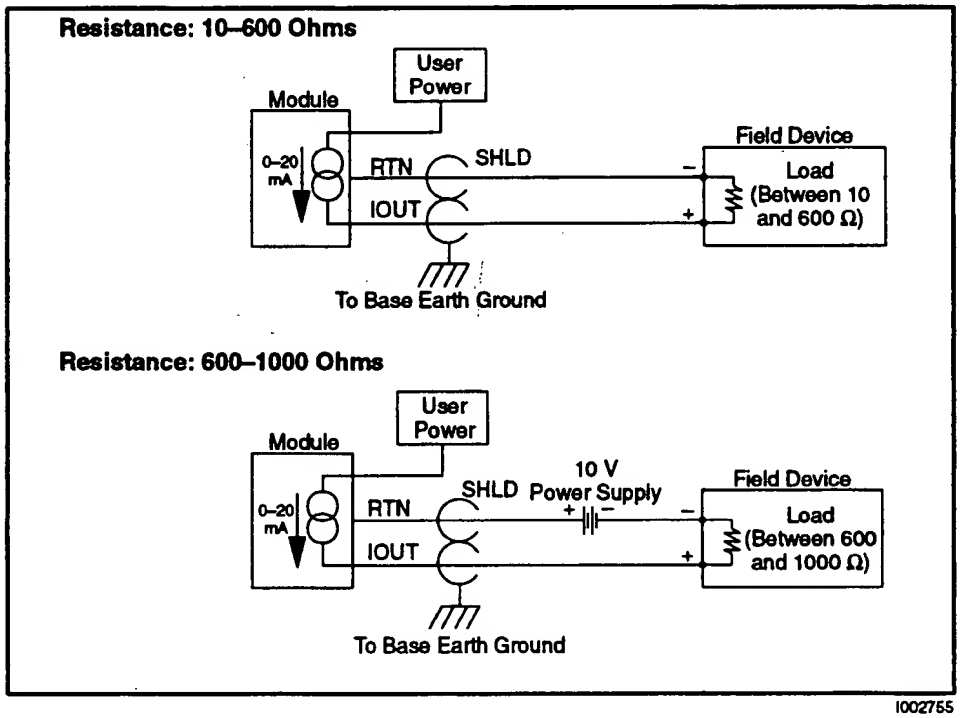

Figure 2-1 Current Output Circuit

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Signal Wire Carrying Voltage

To help ensure accuracy within module specifications, consider the following in choosing wire that carries voltage:

- Load imposed by the field device
- Type and length of wire
- Wiring practices

The load imposed by a field device must be at least 5000 Ω. The maximum capacitance that can be driven by the output is 100 pF. The maximum cable length is a function of cable capacitance. To determine the maximum distance for a given cable, obtain the nominal value of cable capacitance per unit length as given by the manufacturer. Use this value in the following equation.

$$\textit{Maximum cable length} = \frac{100\,pF}{\textit{Nominal cable capacitance (per unit length)}}$$

NOTE: Nominal capacitance is capacitance between conductors. However, if one conductor is connected to the shield via a grounded power supply, the nominal value roughly doubles.

You can use the length and conductor resistance of the cable to find the fixed error appearing at the field device. To determine the fixed error, use the following equation.

$$\textit{Fixed error (\%)} = \left[1 - \frac{R1}{R1 + (2 \times CL \times RFT)}\right] \times 100$$

where

R1 = field load resistance
CL = cable length
RFT = conductor resistance (Ω/unit length)

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2.3 Wiring and Installing the Terminal Block

Terminal Block Options

Figure 2-2 shows the two terminal block types that are available for use with the analog I/O modules. Connector PPX:2587705–8006 is shipped with the modules. However, you can order the other connector, PPX:2587705–8002, and wire it identically. If you are replacing double-wide analog modules with single-wide analog modules, you can simply install the new modules and attach the old, wired terminal blocks.

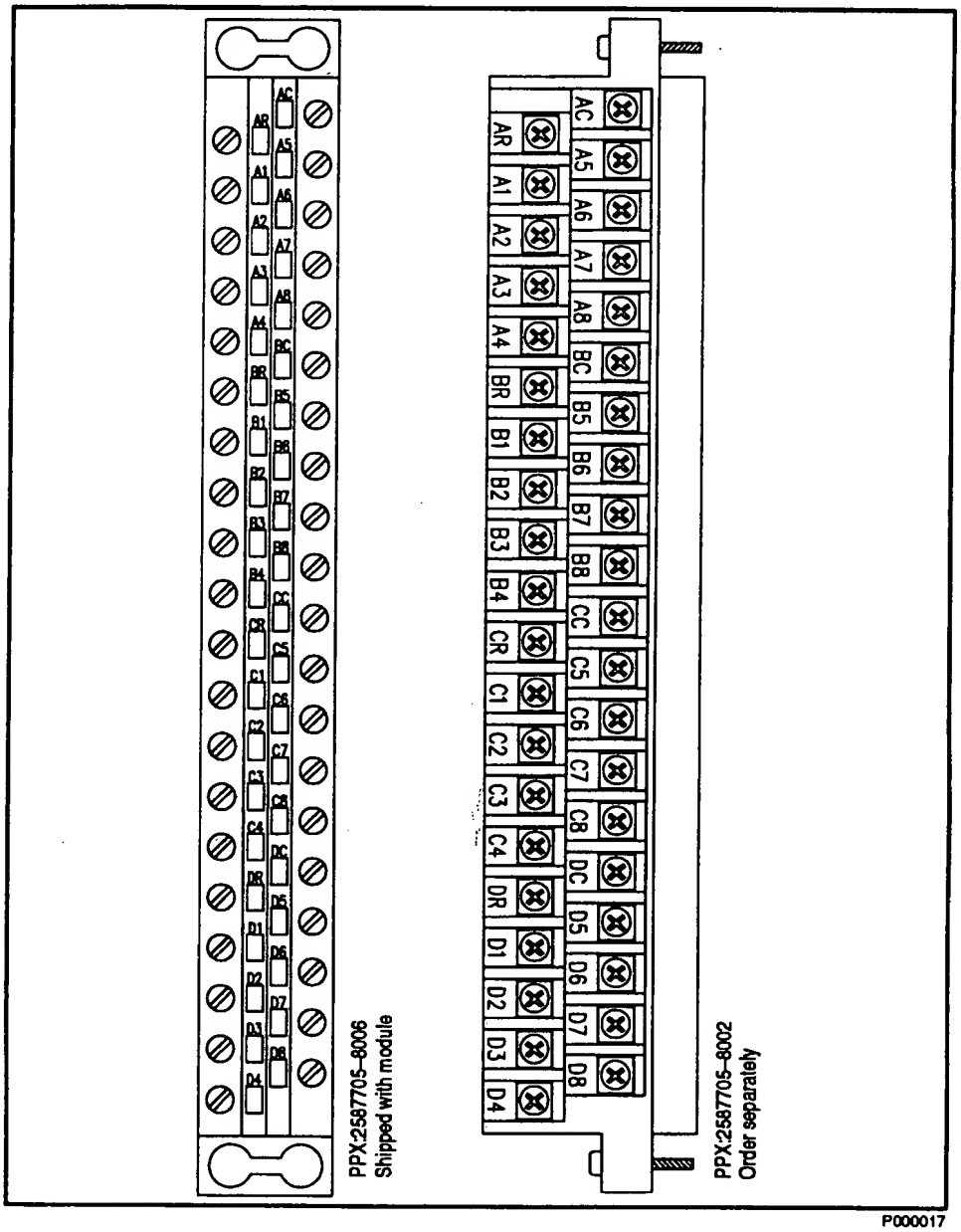

Figure 2-2 Terminal Blocks

Wiring the Terminal Block

You can wire the terminal block before or after it is attached to the module.

1. Strip back the insulation on the wires 0.25″ or 1.0 cm. Use a 14–24 AWG or 0.18–1.5 mm^2 wire, either stranded or solid-type. You may attach a spade or a ring lug (amp 34141) to the end of the wire if allowed by the connector type. Refer to Figure 2-3.
2. Using the appropriate pinout as a wiring guide (Figure 2-4), start with the D terminals and loosen the terminal block screws.
3. Connect the end of the wire to the loosened terminal block screw, and tighten firmly. Once the Ds are completed, tighten the C terminals, and continue until the terminal block is completely wired.
4. Ensure that all wires have good connections. Without good connections, the module does not operate properly.

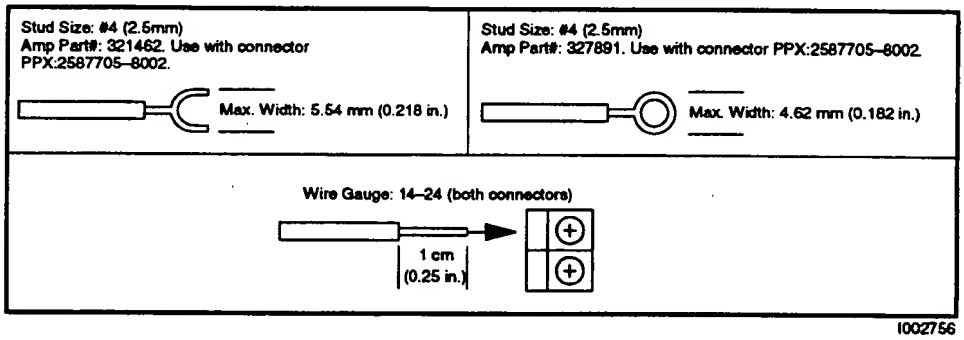

Figure 2-3 Wire Gauge and Stud Sizes

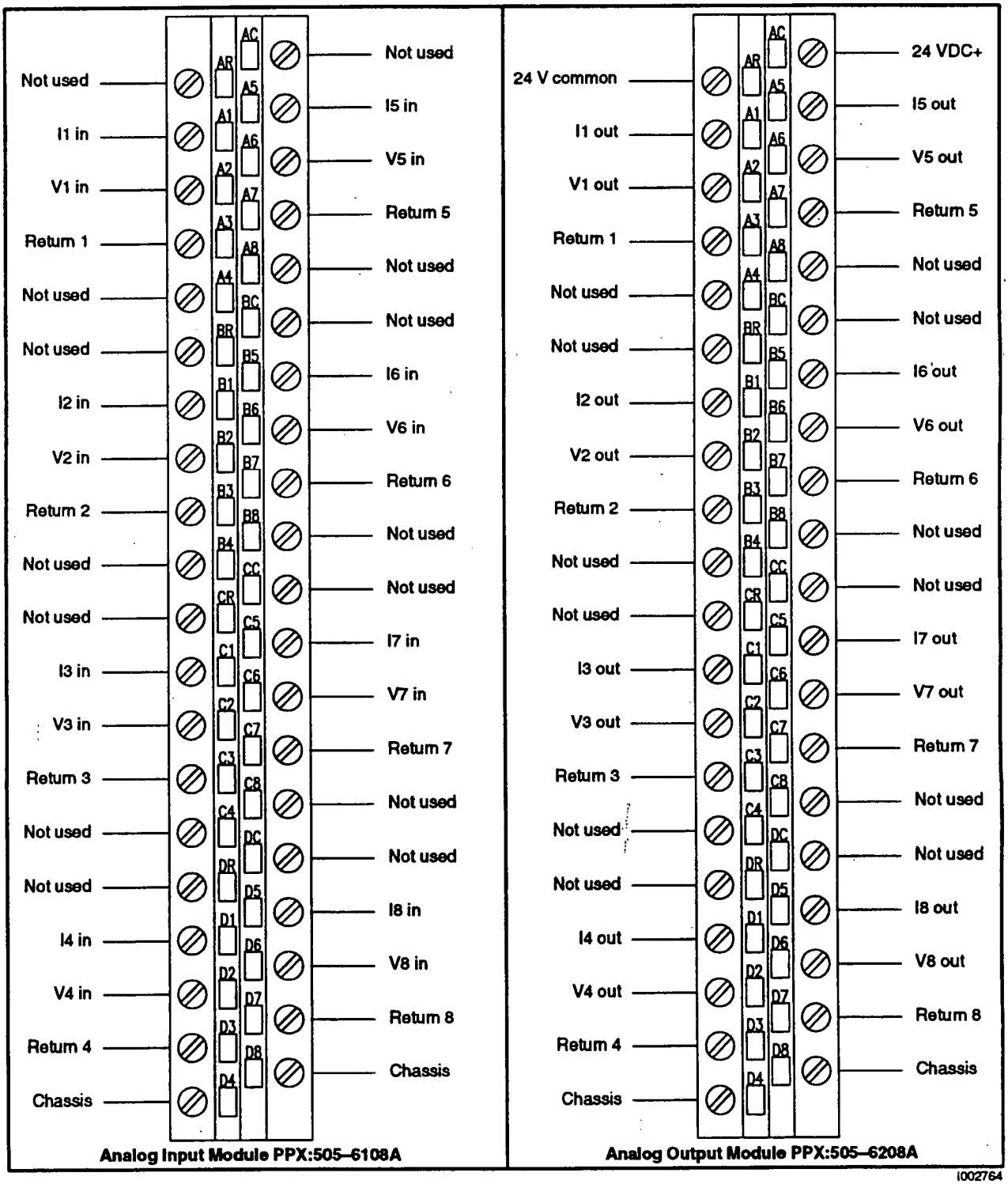

Figure 2-4 Pinouts

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Selecting Voltage or Current Inputs for the Analog Input Module

The Analog Input Module has eight input channels. Each of the eight channels may be selected to receive either voltage or current as the incoming analog signal.

- To wire voltage input signals, wire the input signal directly to the voltage input point.
- To wire current input signals, you must jumper the voltage input point to the current input point for that channel.

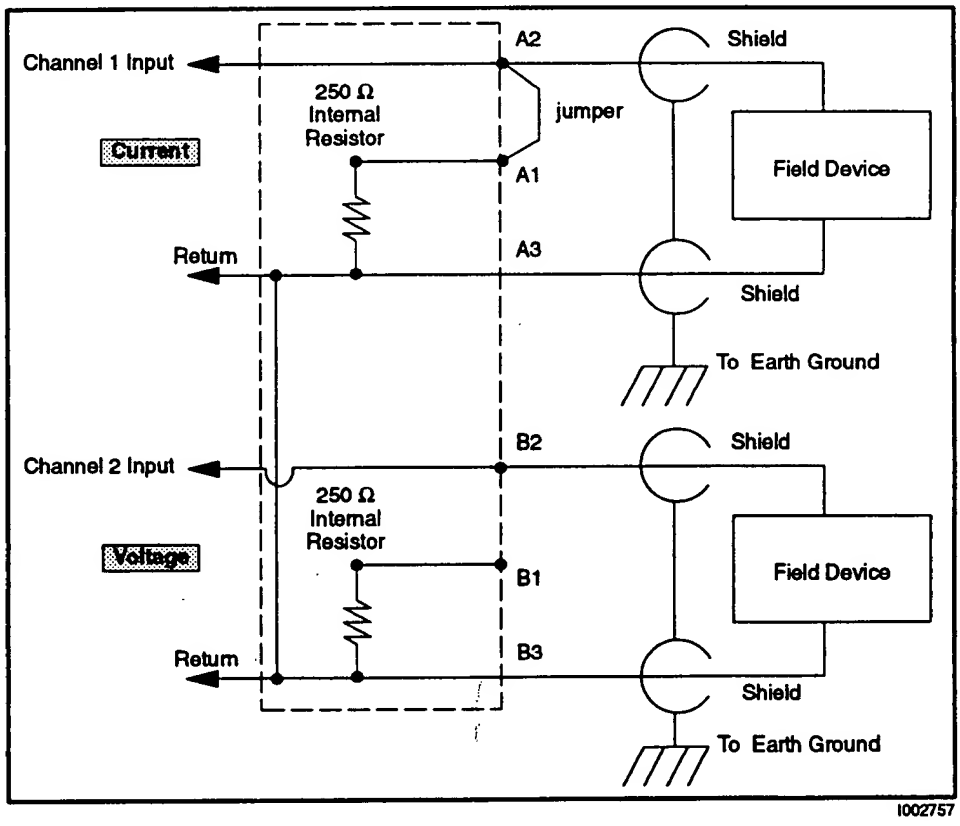

Figure 2-5 Analog Input Module: Field Wiring for Current/Voltage

Figure 2-6 through Figure 2-8 show typical connections for Analog Input and Analog Output Modules.

Figure 2-6 and Figure 2-7 show Channel 1 of the Analog Input Module configured for current and wired to a transmitter.

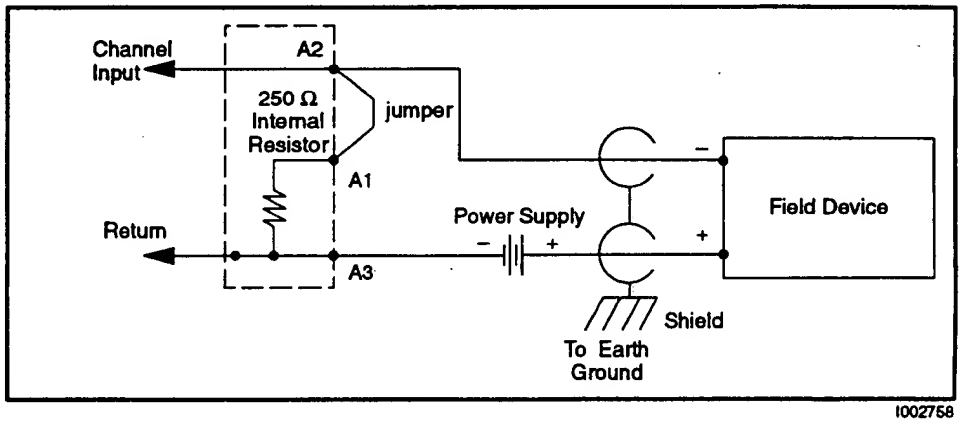

Figure 2-6 Analog Input Module: Field Wiring for 2-wire Transmitter

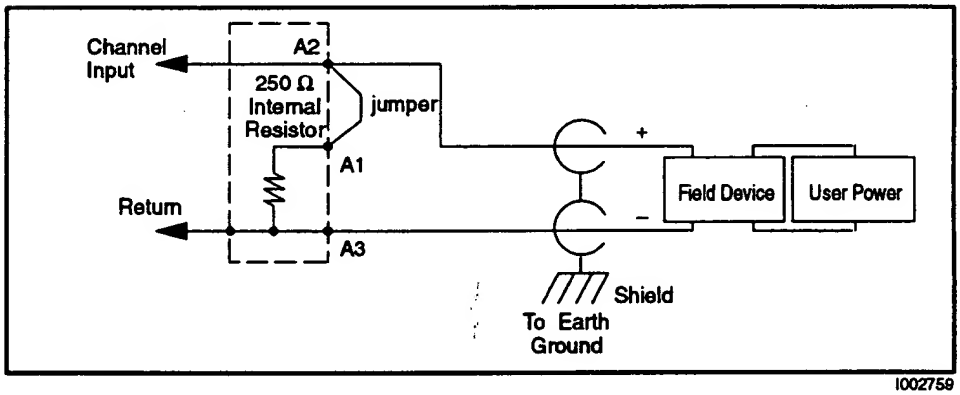

Figure 2-7 Analog Input Module: Field Wiring for 4-wire Transmitter

In the Analog Output Module, output voltage and current are provided simultaneously. As shown in Figure 2-8, you can wire each channel for current, voltage, or both.

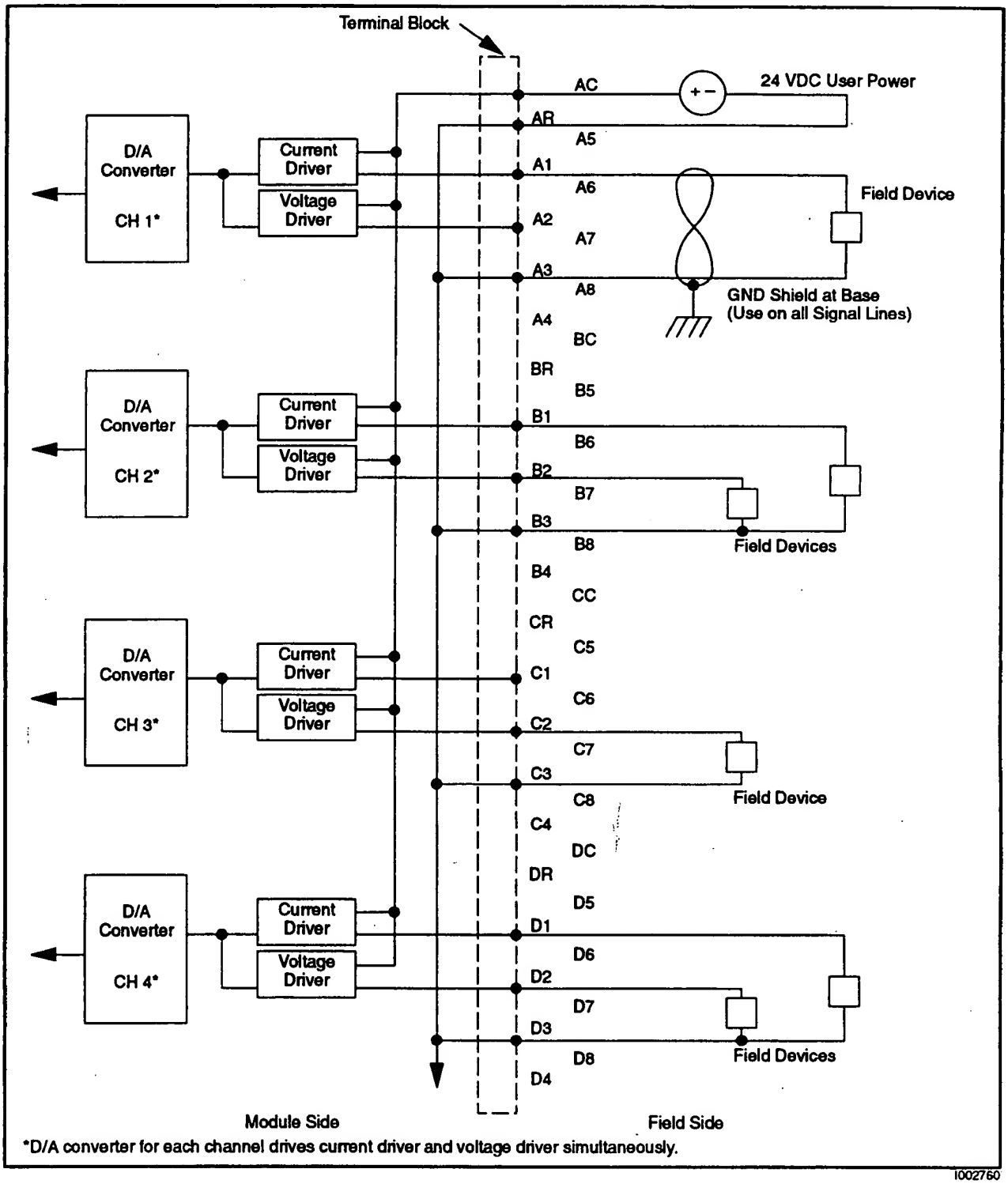

Figure 2-8 Analog Output Module: Typical 4-channel Connection

2.4 Inserting the Module

These analog I/O modules are single-wide. You can install either module in any unused I/O slot. However, avoid installing the modules next to high-energy switching modules or other potential sources of electromagnetic interference (EMI). Install the module in the same manner as any other Series 505 I/O module. To minimize the possibility of electrostatic damage to the components, do not touch the printed circuit board while you are inserting the module. Refer to Figure 2-9.

⚠WARNING **To minimize the risk of personal injury or property damage, disable all power to the system before installing or removing I/O modules.**

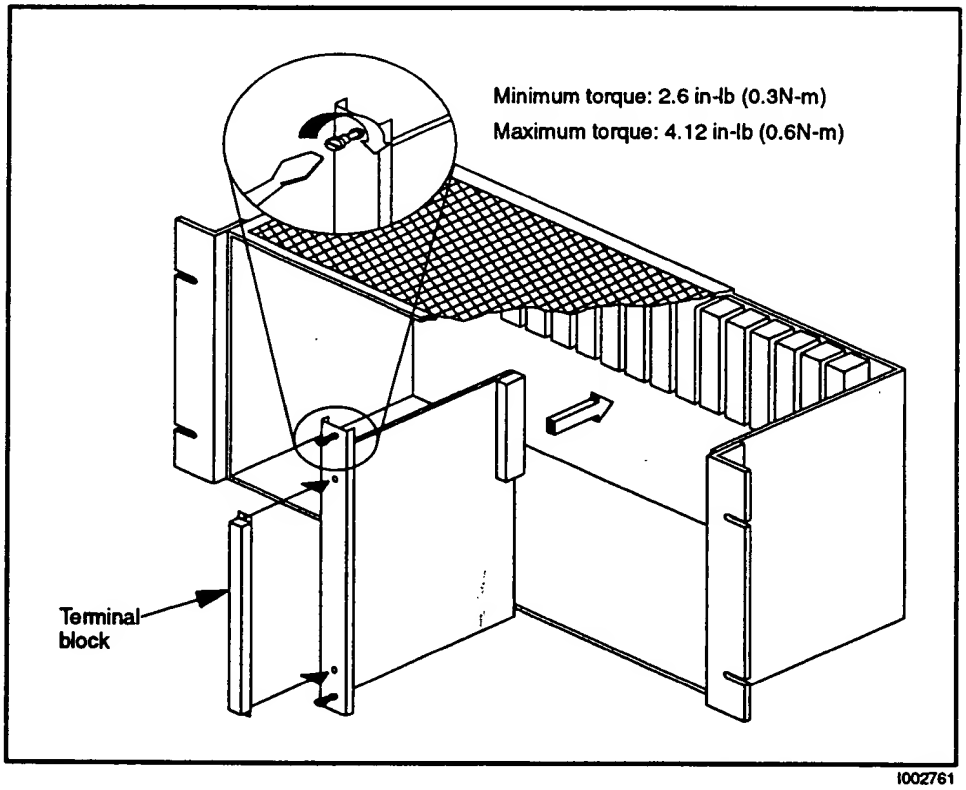

Figure 2-9 Installing the Analog Module

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Apply Power

Apply power only to the base. Configure the I/O. See Section 2.5 on configuring the I/O.

Now that the terminal block is installed and the module is configured, restore all user-supplied power to the base.

NOTE: If more than one module is to be installed, do not restore power until all modules have been installed.

If no problems are detected when power is supplied to the module, the status indicator on the front of the module lights. If the status indicator is not on or goes out during operation, the module has detected a failure. To correct the failure, refer to Chapter 3 on troubleshooting.

After you have inserted the module into the base, you must register the module in PLC memory.

NOTE: If you do not register the module, the PLC logs a nonfatal error; however, the module LED status indicator remains on.

Configure the analog modules as 8-point word as shown in Table 2-1.

Table 2-1 Module I/O Values

Module	WX	WY
PPX:505–6108-A 8-channel analog input module	08	00
PPX:505–6208-A 8-channel analog output module	00	08

Figure 2-10 shows the typical screen used when configuring I/O (base 0, modules installed in slots 1 and 2).

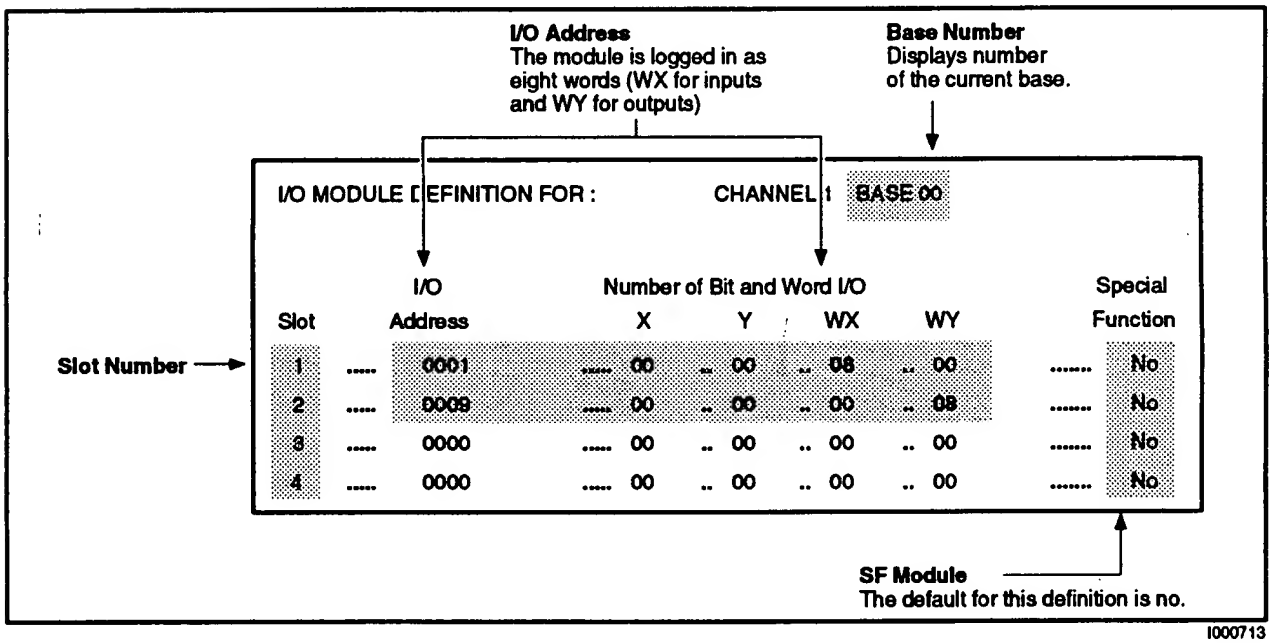

Figure 2-10 Sample I/O Module Definition Chart

For more information on configuring I/O, refer to your TISOFT user manual.

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Chapter 3
Troubleshooting and Maintenance

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3.1 Status Indicator

The LED status indicator and the programming device indicate whether the module is operating correctly. Table 3-1 lists symptoms, possible causes, and corrective actions to take if the module is not operating correctly.

Table 3-1 Troubleshooting Chart

Symptom	Probable Cause	Corrective Action
LED is not on	Not receiving user power—output module only	Check power supply and connections
	Blown fuse—output module only	Check for overvoltage or reversed polarity; replace fuse
	Self-diagnostics fail	Return module for repair
	Base power is off	Turn base power on
Incorrect readings	Connections wrong	Trace wiring connections
	Signal wire noise	Use shielded wire and separate from power wiring
	Module not configured	Check I/O configuration
	Module incorrectly calibrated	Recalibrate the module
	Signal source error—input module only	Verify that signal source levels are in range (Figure 1-3)
CPU nonfatal error because of module	Module configured wrong	Reconfigure the module
	Module failed	Check items under *LED is not on*; if the actions listed do not correct the problem, return the module for repair

3.2 Replacing the Fuse

Figure 3-1 shows the location of the output module fuse. Replace it with the fuse shown.

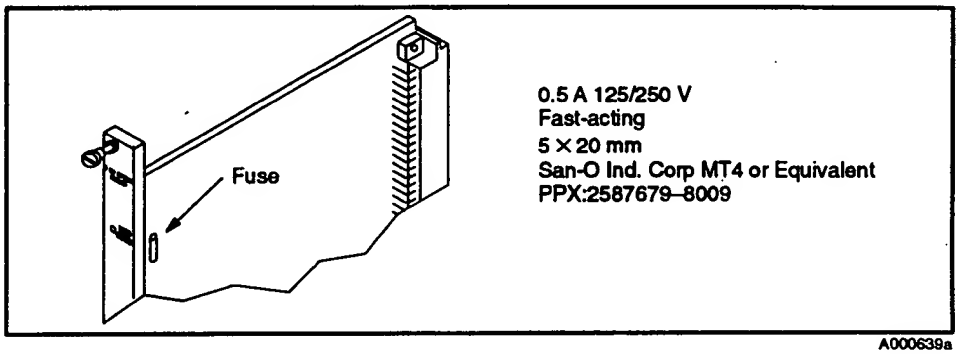

Figure 3-1 Output Module Fuse Location and Replacement Value

Use the following procedure to replace the fuse.

⚠WARNING **To minimize the risk of personal injury or property damage, disable all power to the module before replacing a fuse.**

1. If the wires are too short for you to pull the module out to reach the fuse, disconnect the terminal block from the module.
2. Remove the module from the base.
3. Replace the blown fuse.
4. Insert the module into the base.
5. Connect the terminal block (if necessary).
6. Power up the system.

If you cannot correct the problem, contact your Siemens Industrial Automation, Inc. distributor for technical assistance.

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3.3 Calibration Guidelines

The modules are calibrated during manufacture and should not need to be calibrated again to operate properly; however, a maintenance schedule to check accuracy every six to twelve months is recommended.

If the accuracy is not within ±0.5% tolerance at 25°C, recalibrate the module. You must calibrate the module with the CPU in program mode, not in run mode.

Calibrate the module with or without a Euro-extender card (Euroboard) using the procedures outlined in the following sections.

⚠CAUTION

To help avoid potential damage to equipment, use a non-metallic screwdriver to calibrate the module. Do not use a metallic screwdriver.

⚠WARNING

To minimize the risk of personal injury or property damage, do not touch the printed circuit board during the calibration procedure while the system is powered up.

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3.4 Calibrating Analog Input Modules

To calibrate the input module, follow this procedure.

1. Disable system and user power.
2. Disconnect the field wiring.
3. *If you are using a Euro-extender card (Euroboard):*

   Remove the module from the base.

   Insert the extender card into the I/O slot that the module occupied. You may use a Schroff, Inc. Test adapter board.

   Insert the module into the extender card (Figure 3-2). This provides access to the calibration potentiometer and input range select jumper.

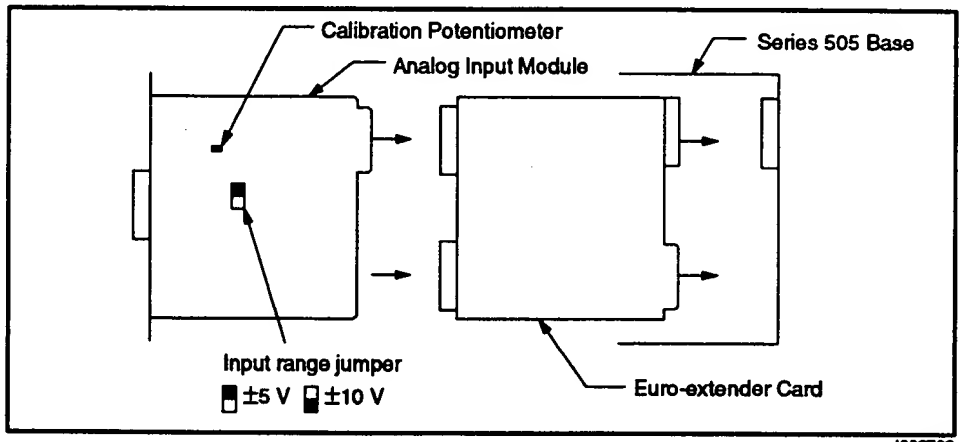

Figure 3-2 Euro-extender Card Assembly for Analog Input

If you are not using a Euro-extender card:

Remove all I/O modules from the base.

Select voltage input range as shown in Figure 3-2.

Move the Analog Input Module to the far left (I/O slot 1) to allow maximum space to reach and adjust the potentiometer.

4. Power up the system and allow the module to reach its operating temperature (usually about 30 minutes, if cold).
5. Connect a programming device to the controller.

   If you are not using a Euro-extender card, configure the Analog Input module in slot 1.

6. Prompt the programming device to display the module points and their associated values.

7. Send +5.000 V to all input points (+10.000 V with the ±10 V input range).

8. Locate the calibration potentiometer on the circuit board (Figure 3-2). Turn the screw with a non-metallic screwdriver until the programming screen shows all addresses at an average of +32000.

9. Send –5.000 V to all input points (–10.000 V with the ±10 V input range).

10. Turn the screw on the calibration potentiometer until all the addresses read an average of –32000.

11. Input +5.000 V to all channels (+10.000 V with the ±10 V input range).

12. Verify that all addresses read +32000 +129/–128. If not, return to step 9 and ensure that the calibration voltage source is accurate to three decimal places.

13. Disable all power to the system.

14. *If you are using a Euro-extender card:*

    Remove it and insert the module into the I/O slots.

    Connect the field wiring.

    If you are not using a Euro-extender card:

    Replace all I/O modules and the analog module in the proper slots.

    Reconnect terminal block wiring.

    Reconfigure the WX input point for the Analog Input Module.

    Reconfigure slot 1 to its original state.

15. Power up the system.

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3.5 Calibrating Analog Output Modules

To calibrate the output module, follow this procedure.

1. Disable system and user power.
2. Disconnect all loads and field wiring (except user power).
3. *If you are using a Euro-extender card (Euroboard):*

   Remove the module from the base.

   Insert the extender card into the I/O slot that the module occupied. You may use a Schroff, Inc. Test adapter board.

   Insert the module into the extender card (Figure 3-3). This provides access to the calibration potentiometer.

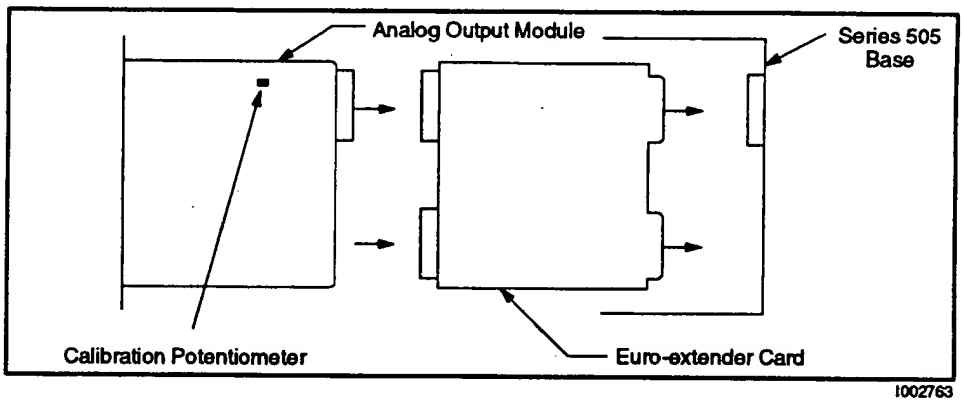

Figure 3-3 Euro-extender Card Assembly for Analog Output

If you are not using a Euro-extender card:

Remove all I/O modules from the base.

Move the Analog Output module to the far left (I/O slot 1) to allow maximum space to reach and adjust the potentiometer.

4. Power up the system and allow the module to reach its operating temperature (usually about 30 minutes, if cold).
5. Connect a programming device to the controller.
6. *If you are not using a Euro-extender card,* configure the Analog Output module in slot 1.
7. Connect a 5.1k-Ω ±5% load to the voltage outputs and a 100-Ω ±5% load to the current outputs.
8. Write 32000 to all channels.

9. Measure all voltage and current channels. Using the current outputs, calculate the mean of the output value, then find the channel whose output is closest to this calculated value.

10. Locate the calibration potentiometer on the circuit board (Figure 3-3). Using the channel which has an output closest to the mean output value, adjust to 20.000 mA at 25° C by using the calibration potentiometer.

11. Check that voltage outputs on channels are 10.000 V ±50 mV, and that the current output of each channel is 20.00 mA ±0.1 mA. If not, return to step 7. Ensure that the calibration loads are connected properly.

    The calibration procedure is complete at this point.

12. Disable all power to the system.

13. *If you are using a Euro-extender card:*

    Remove it and insert the module into the I/O slots.

    Connect all loads and field wiring to the module.

    If you are not using a Euro-extender card:

    Replace all I/O modules and the analog module in the proper slots.

    Reconnect terminal block wiring.

    Reconfigure the WY output point for the Analog Output Module.

    Reconfigure slot 1 to its original state.

14. Power up the system.